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IMPROVING THE EFFICIENCY OF BRIQUETTE PRODUCTION THROUGH DRYING OF COAL DUST

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Abstract

This article investigates the kinetics of coal fines drying in a contact drum apparatus equipped with a rapidly rotating rotor. The study focuses on the experimental determination of the drying curve and the drying rate curve, which are essential for characterizing the moisture removal process of fine coal particles. The methodology involves monitoring temperature and moisture content variations during contact drying, followed by the calculation of drying rates at different process stages. Based on general theoretical principles of drying and its governing laws, a detailed physical picture of the drying process is presented, including the periods of constant and falling drying rates. Special attention is given to the influence of particle size, initial moisture content, and contact conditions on the overall drying efficiency. The results provide a clearer understanding of heat and mass transfer mechanisms in contact drum drying, offering practical recommendations for optimizing briquette production through more energy-efficient and uniform drying of coal fines.

Keywords: Drying kinetics, drying rates, drying rate curve, coal fines, contact drying, briquette production efficiency.

Introduction

Coal is widely recognized as a more economical and accessible raw material for thermal power plants, particularly in remote regions and industrial zones around the world. However, the quality of coal does not always meet the required standards, especially in terms of its mechanical strength, which leads to significant fragmentation during handling and transportation. For this reason, briquetting in specialized equipment using binding agents has become an important method for increasing the combustibility and usability of coal fines [1,2,3].

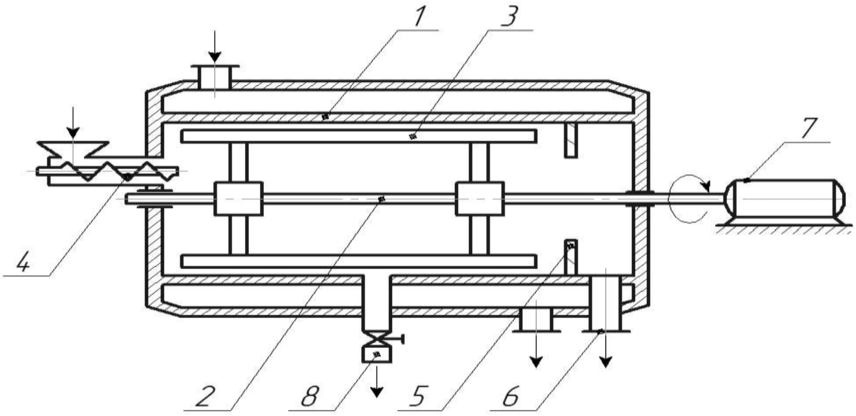
One of the critical technological processes in coal briquetting is the drying of coal fines, since freshly mined coal samples typically contain considerable amounts of moisture. For example, an analysis of the basic physicochemical properties of lignite from the Angren deposit revealed that the initial moisture content of coal fines varies significantly depending on the seam, ranging from 17% to 45% [4]. According to briquetting technology, up to 25% of the mass of coal fines must be supplemented with binding substances obtained from hydrolysis and fat–oil industry by-products [5]. Therefore, it is necessary to reduce the moisture content of coal fines to approximately 15% before adding binding agents, in order to prepare the feed material for briquette pressing.

It should be noted that lignite, regardless of its place of origin, contains up to 60% fines, which must be briquetted with the addition of local binders into briquettes of optimal geometric dimensions [6,7]. A granulometric analysis of coal fines from the Angren deposit, carried out using the sieve method, showed that the fraction of coal dust (particles smaller than 0.2 mm) averages around 8%, with variations between 3% and 14% [8,9].

Materials and Methods

With such a high content of coal dust, the use of conventional convective dryers becomes impractical. In the drying unit proposed in this study, which is equipped with a rapidly rotating rotor, the processes of heat exchange occur 2–4 times more intensively compared to other contact-type apparatuses. This effect is achieved due to the formation of a uniform layer of dispersed material across the entire heated internal surface of the apparatus and the intensive movement of material relative to the hot wall of the drum [10,11].

In the experimental setup, heat is transferred directly from the heated wall of the drum to the layer of dispersed coal fines, eliminating particle carryover since no flow of a heat-carrying drying agent is involved. The apparatus consists of a stationary horizontal heated drum with a rotating rotor fitted with six blades inside (Figure 1). During rotor rotation, the blades lift the coal fines, and the resulting centrifugal force throws the material against the heated inner wall of the drum. The drying energy is provided through the condensation of water vapor, which made it possible to control the heating temperature [12,13,14].



1 – housing; 2 – rotor; 3 – blades; 4 – feeder; 5 – discharge threshold; 6 – outlet of dried product; 7 – electric motor; 8 – sampler.

Figure 1. Schematic diagram of the experimental setup

Results and Discussion

The evaporated moisture was removed from the apparatus in counterflow to the movement of the drying material through a gap near the shaft and condensed in a heat exchanger.

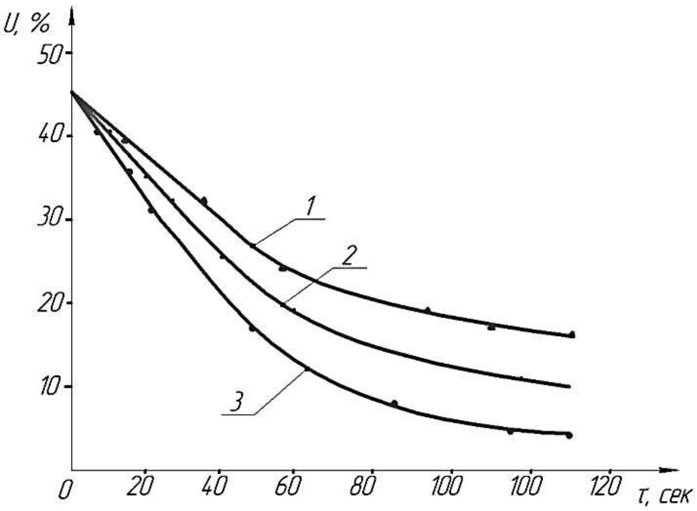
To determine the fundamental regularities of the coal fines drying process, an experimental study of moisture removal kinetics was carried out in a batch mode. Experiments were conducted using raw material with an initial moisture content of 45%. The drying kinetics of coal fines were determined under periodic operation. The experimental procedure was as follows: the apparatus was preheated for a long period (up to 2 hours) until a stationary temperature was reached at all points. After that, the motor was started, the required rotor speed was set, and a portion of coal fines was fed into the apparatus through the feeder. From this moment, at regular time intervals, material samples were taken, and their moisture content was determined by the gravimetric method. The moisture content of the samples was measured by drying them at 105 °C for 3 hours in a drying oven [15,16].

During the drying process, the temperatures of the material and the apparatus wall were monitored at different points along the length and perimeter of the drum. In different experiments, either the wall temperature or the electrical power supplied to the heater was kept constant [17].

The kinetic dependencies of coal fines drying were investigated under the following operating conditions of the apparatus:

- Rotor speed n=200–1000 rpm;
- Wall temperature of the apparatus t_w=110–140°C
- Gap loading coefficient k_z=0.75–1.25

The characteristic drying kinetics curves are presented in Figure 3.



1 – n=300 rpm; 2 –n=500 rpm; 3 –n=700 rpm.

Figure 3. Drying kinetics curves of coal fines.

With sufficient accuracy, the drying kinetics curves up to a residual moisture content of about 30% can be approximated by a straight line, and this moisture level may be considered as the *critical moisture content*. This conclusion is indirectly supported by the material temperature curve: the material temperature remains constant at 100∘C100^{\circ}C100∘C until the moisture content reaches 30%, after which the temperature of the drying material begins to rise [18,19].

From the drying rate curve, it can be observed that up to 30% moisture content the drying process occurs in the first period, i.e., the drying rate remains constant. Analysing the material and heat balance of the drying process shows that the drying rate is proportional to the heat flux received by the material from the wall. It is also noteworthy that the drying curve has a relatively simple form — a linear dependence of the drying rate on the current moisture content. Therefore, the experimental kinetic results can be approximated as follows:

$$\frac{dU}{d\tau} = \left\{ \begin{array}{c} Nnnpu \ \ \ge Ukp \\ \hline N\dfrac{U - Up}{Ukp - Up} npuU \le Ukp \end{array} \right\}$$

Based on the changes in moisture content and material temperature during the drying process, the amount of heat supplied to the material through heat transfer from the heated wall of the apparatus was determined [20]. The experimental results were processed in the form of a dependence of the heat transfer coefficient from the heated wall to the material layer, in accordance with the following formula:

$$\alpha = Q/\left(F \cdot \Delta t_{cp}\right)$$

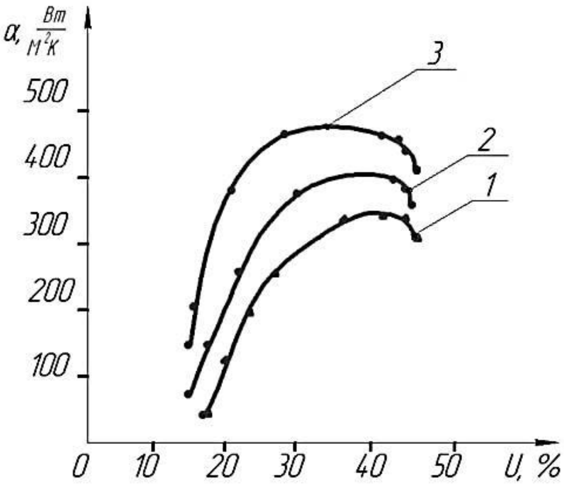
Here, ΔT\Delta TΔT represents the difference between the average wall temperature and the material temperature. In the experiments, to ensure accurate determination of the heat transfer coefficient, the temperature difference was maintained at more than 20 °C. The value of $F=0.17$ m^2 corresponds to the internal surface area of the apparatus housing. The amount of heat supplied to the material during the drying process was determined based on the heat balance equation:

$$Q = G_c \frac{dU}{d\tau} r + G_c\left(C + C_{\text{B}} U\right)\frac{dt}{d\tau},$$

Where *U* is the mass fraction of moisture in the material, referred to the absolutely dry weight.

The effect of moisture content on heat transfer is shown in Figure 4, where three distinct periods can be observed: one with an increasing value of the heat transfer coefficient α\alphaα, one where α\alphaα remains relatively constant, and one with a decreasing value of α\alphaα. As noted in further experiments, the reduction in the heat transfer coefficient at high moisture contents is associated with poorly organized loading of the material into the apparatus, which prevents effective contact between the material and the heated wall at the beginning of the process [21].

A high heat transfer coefficient α\alphaα corresponds to the removal of surface moisture, and the physical explanation for these high values of the heat transfer coefficient α\alphaα is as follows:



1 –n=300 rpm; 2 –n=500 rpm; 3 –n=700 rpm.

Figure 4. Dependence of the heat transfer coefficient α\alphaα on the moisture content *U* of coal fines.

Firstly, the increase in the contact area between the particle and the hot surface occurs because part of the air layer is filled with liquid.

Secondly, under strong centrifugal fields, moisture may be squeezed out onto the hot surface, which increases the effective heat transfer area.

Thirdly, as the moisture content of the dispersed material changes, the thermophysical properties of the layer also change, affecting the intensity of heat transfer between the layer and the heated wall.

The curves also demonstrate that the rate of heat supply increases rapidly with higher rotor speeds.

Conclusions

The experiments have demonstrated the fundamental feasibility of drying coal fines in a contact apparatus in the form of a thin layer within the gap between the drum and the rotor blades. It was proven that this method eliminates the loss of fine coal particles, thereby preventing environmental pollution. Due to the high heat transfer coefficients, contact-type dryers require significantly smaller overall dimensions compared to conventional convective dryers.

Furthermore, the drying kinetics curves of dispersed materials obtained in the studied apparatus provide the necessary data for calculating the optimal dimensions of the proposed equipment.

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