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Investigation of Processes of Thermal Activation of Coal Materials

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ABSTRACT: This article explores the processes of thermal activation of coal materials and their physical and chemical characteristics. The study includes carbonization and physical activation of coal under various conditions. The results show that thermal activation leads to an increase in ash content and coal content, as well as a decrease in coal yield. Additionally, carbon activation processes using CO_2 have been investigated and the effect of activation duration on weight loss, ash content, coal content and moisture content has been identified. The obtained data can be useful for optimizing the processes of production and use of coal in various fields.

KEYWORDS:coal, hard coal, thermal activation, ash content, 1SCLWS, 1WCSS, 1SP.

I.INTRODUCTION

Methods and technologies for the production of coal adsorbents based on coal represent a diverse set of processes, including the activation and modification of coal materials. These methods are important for improving the adsorption properties of carbon adsorbents and ensuring optimal material characteristics [1–3].

The activation process is one of the key methods used in the production of carbon adsorbents. It involves exposing coal materials to high temperatures in the presence of certain gaseous or chemical agents. Activation contributes to the creation of a porous structure in the material, which increases its surface area and the ability to adsorb various substances. There are various activation methods such as chemical activation using potassium or phosphoric acid, thermal activation at high temperatures, or steam activation [4–6].

Additionally, modification of carbon materials can be applied to further improve their adsorption properties. This process involves chemical or physicochemical changes to the surface of the carbon material in order to increase its specific surface area, change its reactivity, or add functional groups. Modification can be carried out using various reagents, such as acids, bases, or organic compounds [7–10].

The choice of a specific method for the manufacture of carbon adsorbents has a significant impact on their strength and adsorption characteristics. For example, steam activation of carbon materials can create a wider range of pore sizes, which increases their ability to absorb various molecules. At the same time, the choice of certain reagents for modifying the surface of the carbon material can lead to an increase in its selectivity to certain substances or an improvement in its resistance to the environment [11-15].

Thus, the correct choice of the method for preparing carbon adsorbents plays an important role in optimizing their adsorption properties. Based on the analysis performed, it can be concluded that the activation and modification of carbon materials are the key processes that make it possible to achieve the required characteristics of coal adsorbents. These methods provide an increase in the surface and porosity of the material, and also allow you to change its chemical activity. In turn, this affects the strength and adsorption properties of carbon adsorbents, making them more effective for removing pollutants from various media [15–20].

Quarry facilities of the Shargun and Baysuns coal deposits produce conditioned marketable coals of grades: 1SCLWS, 1WCSS, 1SP, which also differ in ash content and accompanying mineral impurities. The purpose of the research was to establish the main indicators of these coals and the effect of thermal and physical activation on their characteristics..

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II. SIGNIFICANCE OF THE SYSTEM

This article explores the processes of thermal activation of coal materials and their physical and chemical characteristics.The study of methodology is explained in section III, section IV covers the experimental results of the study, and section V discusses the future study and conclusion.

III. METHODOLOGY

Physical and chemical characteristics of coal were established according to the requirements of GOST R 56357-2015, GOST 8302-87, GOST 8298-89, TSh12-18:2001. The content of carbon and ash in the samples was determined by the absolute combustion of the material in a tube furnace by the accelerated method according to GOST 2408.1-95.

To obtain activated carbons, carbonization and subsequent physical activation in an inert atmosphere were carried out. Different coal fractions were carbonized in a laboratory fixed bed reactor under the same experimental conditions, where the reactor was heated to 450°C (at a heating rate of 8 K/min) and thermally activated at 850°C using a nitrogen flow of 100 ml/min, and kept within 2 hours.

To designate the resulting activated carbons, the letter "A" was added before the name of the original carbon, which indicated activation (for example, A1SCLWS, A1WCSSand A1SP).

These carbons were then separately activated with carbon dioxide or steam at different burnout levels to study the effect of the activating agent and ash content on the development of the pore structure. Activation using CO_2 was carried out at a temperature of 850°C and a flow rate of 80 ml/min for various time intervals in the same reactor used for carbonization. For carbons activated with CO_2, the nomenclature included the name of the original coal followed by the number 1 (A1SCLWS1, etc.).

IV. EXPERIMENTAL RESULTS

Qualitative characteristics of the original bituminous coal are given in table. 1.

Table 1.
Qualitative characteristics of coal deposits

Indicators	Brand (group)		
	1SCLWS	1WCSS	1SP
Type of regulatory document	TSh12-18:1998	TSh12-18:1998	TSh12-20:2003
Piece size, mm	18-90	≤13	20-120
Ash content, % no more	25,0	30,0	32,0
Mass fraction of total moisture, % no more	10,0	10,0	14,0
Lower calorific value, kcal/kg	6200	5400	4600

Based on the data in table. 1, the analysis of hard coals allows us to highlight the following results that can be used to create adsorbents:

the investigated samples of hard coals have different sizes of pieces. Shargun coal (1SCLWS) has a lump size in the range of 18-90 mm, while Boysun coal (1WCSS) has a lump size of no more than 13 mm. This information makes it possible to determine the optimal granule size for adsorbents, depending on the required characteristics and application;

all coal samples have a certain ash content. Shargun coal (1SCLWS) has an ash content of no more than 25%, while Boysun coal (1WCSS, 1SP) has an ash content of 30% or more. This makes it possible to take into account the ash content in the development of adsorbents and the choice of binders in order to minimize the effect of ash on their effectiveness;

bituminous coals of both deposits contain a certain amount of moisture. The maximum mass fraction of total moisture is 10% for both coals, with the exception of Boysun coal, where it is 14%. This is important to take into account when determining the optimal moisture content in adsorbents and methods for their drying;

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bituminous coals of the Shargun and Boysun deposits have different lower calorific value. Shargun coal has a higher net calorific value of 6200 kcal/kg, while Boysun coal has 5400 kcal/kg. Using the results of the analysis of hard coals, it is possible to determine the optimal composition for creating adsorbents based on them.

Also, knowing the size of the pieces of coal, it is possible to determine the optimal size of the adsorbent granules, which will ensure the efficiency of the adsorption process. The mass fraction of total moisture and the lower calorific value of hard coal are also important for determining the parameters of the drying process and the energy efficiency of the adsorbent.

Coal samples heat-treated at a temperature of 450ºC for 1 hour are characterized by the following characteristics (Table 2).

Analyzing changes in the ash content and yield of coal during the carbonization of hard coals of grades 1SCLWS, 1WCSS and 1SP, it can be assumed that the ash content of coal samples increases during heat treatment and with an increase in its duration. Sample 1SCLWS has the lowest ash content (26.47%), while sample 1SP has the highest ash content (33.44%). This may be due to the different composition of the initial coals and their response to the carbonization process at a given temperature.

Table 2.

Indicators	Образец		
	1SCLWS	1WCSS	1SP
Mass loss, %	13,1	9,3	10,3
Ash content, %	26,47	30,87	33,44
Coal content, %	68,01	59,32	49,72
Humidity, %	4,10	3,80	4,60

The yield of coal (from the mass of the original coal) also decreases during heat treatment (as well as with an increase in heat treatment time). Sample 1SCLWS has the highest yield of coal (68.01%), while sample 1TP has the lowest yield (49.72%). This can be explained by various factors, such as weight loss due to the burning of some of the coal and the removal of water during the heat treatment process.

The initial moisture content of coals also affects the change in ash content and coal yield. By convention, wetter coals have a higher ash content. Moisture content of coals is up to 10, 10 and 14% for grades 1SCLWS, 1WCSS and 1SP, respectively. Therefore, the 1TP sample with the highest moisture content also has the highest ash content.

Thus, the process of carbonization at a temperature of 450ºC leads to an increase in the ash content of coals and a decrease in the yield of coal. This is due to the loss of mass as a result of burning out part of the coal, the removal of physically and chemically bound water, as well as differences in the initial moisture content and composition of the coals. These results may be useful for further study of carbonization processes and optimization of coal production.

In table. 3 shows results showing activation time, overall yield, burnout, ash content, and specific surface area of the thermally activated and steam activated carbons produced in this study. As predicted, the carbonization process leads to an increase in the ash content of the samples. For each series of activated carbons, a linear relationship is observed between the degree of burnout and the activation time. At the same time, the reaction rate upon steam activation is comparable for all three coal samples, including carbons activated with CO2.

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Table 3
Characteristics of coals depending on the duration of thermal activation (T) using CO2

Indicators	Образец											
	A1SCLWS1				A1WCSS1				A1SP1			
T, h	-	1	2	3	-	1	2	3	-	1	2	3
Mass loss, %	0	8,1	16,7	21,7	0	14	22,1	27,2	0	8,5	11,9	14,8
Ash content, %	26,5	23,2	22,9	21,8	30,9	28,7	27,2	26,9	33,4	31,2	30,9	30,1
Coal content, %	68,0	64,5	65,2	65,8	59,3	55,5	56,8	57,1	49,7	45,2	47,3	47,9
Humidity, %	4,1	3,6	3,3	2,9	3,8	2,9	2,5	2,4	4,6	2,8	2,7	2,6

**-duration of carbonization - 1 hour.*

Analyzing the data from Table 3, which characterize changes in the characteristics of coals during thermal activation using CO2 anhydride carbonate as an activator, it can be seen that the weight loss of coal increases with increasing duration of thermal activation. Samples A1SCLWS1, A1WCSS1 and A1SP1, subjected to activation for 1 hour, show a weight loss of 8.1; 14.0 and 8.5% respectively. With an activation duration of 3 hours, the mass loss increases to 21.7; 27.2 and 14.8%, respectively. This may indicate the decomposition of the organic components of coal and the release of gas products during thermal activation.

The ash content of coal also changes during thermal activation. There is a decrease in the ash content of coal with an increase in the duration of activation. For example, sample A1SCLWS1 has an ash content of 26.5% which drops to 21.8% after 3 hours of activation. A similar decrease in ash content is also observed for other samples (A1WCSS1 and A1SP1). This may be due to the release of some mineral components in the form of gaseous products or their dissolution during the activation process.

The content of carbon in the samples also varies depending on the duration of activation. With increasing activation time, the carbon content may change slightly. For example, sample A1SCLWS1 has a carbon content of 68.0%, which decreases slightly after 2 and 3 hours of activation. Similar minor changes are also observed for other samples (A1WCSS1 и A1SP1).

The moisture content of the coals also decreases with increasing duration of activation. For example, in sample A1SCLWS1, moisture content decreases from 4.1% to 2.9% after 3 hours of activation. Similar tendencies are also observed for other samples (A1WCSS1 и A1SP1). This is due to the release of water in the form of gas products during the activation process.

Thus, thermal activation of coal using CO2 affects weight loss, ash content, coal content and coal moisture. These changes are associated with the processes of decomposition of organic components, the release of gas products, and the leaching of mineral components during activation.

V. CONCLUSION AND FUTURE WORK

Sorry for misunderstanding. Here is a summary of the data of both pieces of information:

The study of the processes of thermal activation of coal materials included carbonization and subsequent physical activation in an inert atmosphere. Various coal fractions were subjected to carbonization at 450°C and then thermal activation at 850°C for 2 hours. The results showed that the ash content and coal content increase with thermal activation, and the coal yield decreases.

Coal samples were activated at 850°C using CO2 flow for various time intervals. The results showed that the duration of activation affects the weight loss, ash content, coal content and coal moisture. A longer activation led to a greater weight loss and a decrease in the ash content of coal. These results may be useful for optimizing coal activation processes.

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