Manufacture of Briquetted and Granulated Fuels from Lignite with Biobinders and Heated Die

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Abstract

The experimental data are presented describing the processes of briquetted and granular smokeless fuels production from lignite with the use of heated die and cheap biobinders. The influence of moisture and biobinder content, pressure, temperature, time of process on the properties of resulting fuels was studied. Briquettes and granules with calorific value 24–27 MJ/kg and with good mechanical properties were produced at the selected process parameters. They can be used as smokeless fuels and reducing agents.

INTRODUCTION

One of large-scale consumers of coal fuel (accounting for about 6–10 mln t of coal per year) is household facilities. High-quality household fuel should have large heat of combustion (calorific value), definite size (+13 mm), sufficient strength, stability to moisture and heating.

High-quality household fuel is manufactured from lignite by briquetting and granulation. Briquetting of younger lignite (W = 50–60 %) according to the classical technology under the pressure of 100–120 MPa and humidity 12–18 % has been introduced into industry [1, 2]. In order to briquet more mature lignite (W = 30–40 %), higher pressure (>200 MPa) is necessary, which causes definite difficulties for the industrial implementation of the technologies. The Kansk-Achinsk lignite belongs to this latter type of coal [3].

The necessity to process the Kansk-Achinsk lignite into briquettes or granules is caused not only by the considerations connected with an increase in the fuel quality but also by the trend to fracturing during storage with the formation of small particles and spontaneous ignition.

The best kind of the household fuel is so-called smokeless fuel which is ecologically safer than usual coal. The main technological stage of the processes of obtaining smokeless fuel is thermal treatment of the resulting briquettes and granules [4–6].

Definite advances have been recently achieved in the area of biotechnological processing of coal. Bioprocessing of coal is possible both under aerobic and anaerobic conditions using various strains of microorganisms [7–9].

Previous investigations into bioprocessing of lignite showed that substantial chemical and structural transformations occur in the organic mass of coal during its biotransformation under aerobic conditions with the adapted strains of microorganisms [10, 11]. The products of biotransformation can be used as a binder (biological binder, or biobinder) for briquetting (dried products) and granulation (biocoal suspensions) of lignite [12–14].

In the present paper we report on the results of investigations of briquetting and granulation of the Borodino and Berezovo lignite from the Kansk-Achinsk coal basin using the products of biological processing of coal as binding agents and under isothermal exposure of the coal charge under pressure in a heated die.

EXPERIMENTAL

The Borodino and Berezovo lignite samples were used in the investigation of briquetting and granulation. The parameters of lignite samples are listed in Table 1.

Dried products obtained as a result of microbiological processing of lignite under aerobic conditions with the adapted strains of microorganisms Acinetobacter SP10 and Pseudomonas SP2 and SP57 were used as a biological binder.

For briquetting with biological binder, the Borodino lignite with particle size 0–3.0 mm was used together with biological binder with particle size 0–0.63 mm; humidity was varied within 10–22 %. The component ratio (coal : biological binder) in the charge for briquetting was 60 : 40, 70 : 30, 80 : 20 and 90 : 10. Specific pressure used for pressing was 100, 120 and 140 MPa.

Investigations into granulation of the Borodino lignite were carried out using a plate granulator with plate diameter of 1 m and tilting angle varied within 0–90°; rotation frequency was varied within 0–100 rpm. Coal with particle size of 200 mm was used for granulation. The resulting granules were about 30 mm in diameter.

TABLE 1

Characteristics of the Kansk-Achinsk lignite

Parameter	Borodino	Berezovo
Content of the volatile substances V^{daf}, % mass	47.4	48.3
Ash content A^{d}, %	5.4	4.8
Humidity W_t^r, %	32	31.2
Elemental composition, % mass:		
C^{daf}	74.7	70.2
H^{daf}	5.0	5.1
N^{daf}	0.9	0.72
S^{daf}	0.5	0.37
O^{daf}	19.4	22.6
Specific calorific value, MJ/kg	14.5	14.7

The binding agents used for granulation of the Borodino lignite were biocoal suspensions with the humidity of 70 %, which were obtained from the coal by its biological processing. Biological suspensions are creamy oil-like liquids with the dynamic viscosity about 200 Pa s. An increased viscosity of biosuspensions did not allow their direct admittance to the sprayers. In order to eliminate this shortcoming, we diluted the biocoal suspensions with water varying the concentration from 30 to 95 %.

The Berezovo lignite with the size of 0–3 mm was subjected to briquetting in a heated die under the following technological conditions:

Briquetting parameter	Range investigated
Initial charge temperature, °C	25–140
Initial humidity of the charge, %	2–29
Specific pressure of rpesing, MPa	80–150
Exposure of the charge under pressure, s	5–60
Temperature of the die, °C	100–450

Pyrolysis of briquettes and granules was carried out in nitrogen in a pyrolysis reactor 1.8 l in volume with external heating till the final temperature of 450, 500, 550, 600 and 650 °C with the heating rate of 1 °C/min.

The resulting briquettes, granules and solid products of pyrolysis were tested for compression resistance, abrasion resistance and water absorption according to the All-Union State Standard (GOST) 21289–21291–75; their opacity, yield of volatile substances and calorific value were also determined.

Smokelessness of the fuel was determined according to two criteria [4]. A fuel is considered smokeless if it contains volatile substances less than 20 % and if no smoky flame is formed within 90 s during its combustion at a temperature of 850 °C.

RESULTS AND DISCUSSION

Determination of briquetting parameters for the Borodino lignite involving biological binder

The goal of investigation into briquetting of the Borodino lignite with the dried products of its biological processing as a binder was to determine optimal parameters of briquetting resulting in the briquettes of satisfactory strength.

At the initial stage of investigation, we determined the effect of the humidity of coal and biological binder on the strength parameters of the resulting briquettes. One can see in the data shown in Fig. 1 that the strength of the briquettes passes through its maximum when the humidity of the biological binder increases from 10 to 22 %.

An optimal humidity of the biological binder corresponds to a definite compacting pressure, which results in obtaining the briquettes with maximal compression strength. For example, with compacting pressure increased from 100 (see Fig. 1, curve *1*) to 140 MPa (curve *2*) the optimal humidity of pure biological binder corresponding to the maximal strength of the briquettes decreases from 17.0 to 15.5 %. The briquettes obtained under these conditions are characterized by the hardness of 22.2 and 30.6 MPa, respectively.

The next stage of investigation of the Berezovo lignite briquetting with the biological binder provided determination of the minimal content of biological binder in the charge for obtaining high-quality briquettes.

One can see in the data shown in Fig. 2 (curve *2*) that an increase in the content of biological binder in the charge from 10 to 40 % helps increasing the strength of briquettes obtained with the compacting pressure of 120 MPa. The compression strength of the resulting briquettes increases from 12.1 to 17.4 MPa, while the abrasion strength increases from 80.7 to 94.2 %.

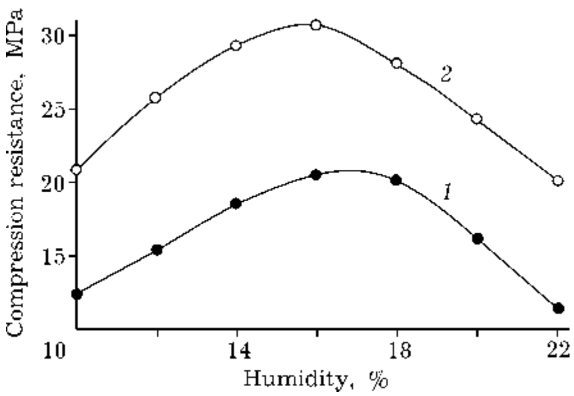

Fig. 1. Effect of humidity of the biologically treated Borodino coal on the strength of briquettes obtained under the compacting pressure of 100 (*1*) and 140 MPa (*2*).

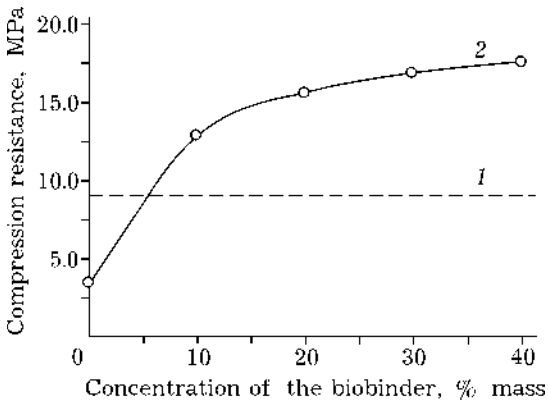

Fig. 2. Effect of the content of biobinder on the strength of briquettes obtained from the Borodino coal: *1* – compression resistance; *2* – normalized parameter of briquette strength.

So, the content of biological binder in the charge should be about 10 % in order to obtain the briquettes of satisfactory quality. The resulting briquettes meet the demands to the compression resistance of lignite briquettes (9 MPa) and their abrasion resistance (77 %).

It should be noted that coal briquetting under the same parameters without biological binder does not allow achieving satisfactory strength of the coal briquettes.

Granulation of the Borodino lignite with the biobinder

It is necessary to use binding agents for coal granulation; in the present work we used the biocoal suspension (biological binder, or biobinder) formed during aerobic biological processing of lignite.

The goal of investigations into granulation of the Borodino lignite was determination of optimal technological parameters: humidity of the coal to be granulated, tilting angle and rotation frequency of the granulator plate, and the characteristics of the biocoal suspensions used as a binder.

It was established in the investigation that the initial humidity of coal (before granulation) has a substantial effect on granulation and on the strength characteristics of the resulting granules.

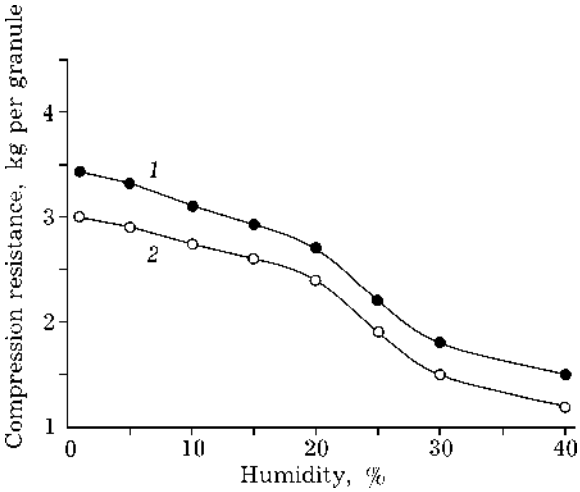

Fig. 3. Effect of humidity of the Borodino lignite on the strength of the resulting granules: *1* – initial granules; *2* – granules dried at 20 °C.

One can see in the data shown in Fig. 3 that within the humidity range up to 20 % the initial humidity of the coal has only slight effect on granulation process and on the strength characteristics of the resulting granules.

Initial granules (see Fig. 3, curve *1*) for the initial coal humidity of 20 % have compression resistance 2.7 kg per one granule, while the resistance of the granules dried at 20 °C (curve *2*) is 2.9 kg per granule. With a decrease in the initial humidity down to 1 %, the compression resistance increases from 3 for the initial granules to 3.5 kg per granule for the dried ones.

For granulation of the lignite with the initial humidity more than 20 %, the strength of the initial and dried granules decreases, and granulation process becomes unstable.

It was established in the investigation of coal granulation involving the solutions of biocoal suspensions of different concentrations (Fig. 4) that the strength of the initial (curve *1*) and dried (curve *2*) granules increases with an increase in the concentration of biological suspension in solution from 30 to 70 %. However, further increase in the concentration of biological suspension in solution (above 80 %) causes an increase in the viscosity of solution, which brings complications into the granulation process.

It follows from the data shown in Fig. 4 that the strength of both the initial and dried granules passes through its maximum with an increase in the concentration of biobinder. Maximal compression strength corresponds to 70 % concentration of the biobinder and is equal to 3.2 kg per granule for the initial granules and 5.8 kg per granule for those dried at 20 °C.

It was established in the investigation of granulation of the Borodino lignite that optimal operation conditions for the plate granulator 1 m in diameter are: tilting angle 55°, rotation frequency 42 rpm. The resulting granules have satisfactory strength characteristics and can be used to obtain smokeless fuel and carbon reducing agents.

Briquetting of the Berezovo lignite in the heated die

A promising method of obtaining briquettes is briquetting of the lignite without binders in a heated die at a temperature below the point of coal transfer into the plastic state.

The following regularities were established in the investigation of briquetting of the lignite in a heated die under isothermal conditions (see above):

– The strength of briquettes increases with an increase in the chare heating temperature, temperature of the die and compacting pressure;

– The time for the exposure of the charge under pressure necessary to obtain strong bri-

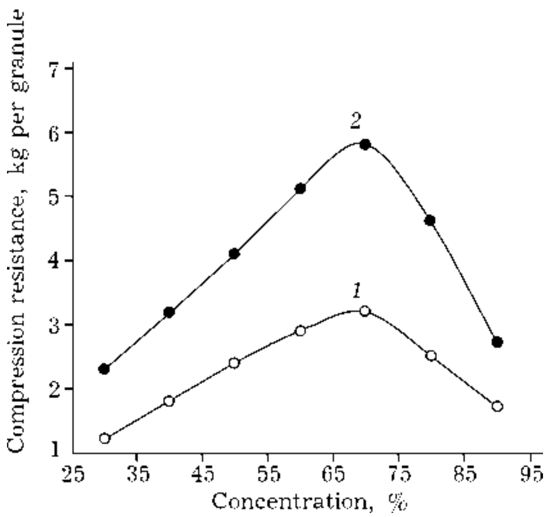

Fig. 4. Effect of concentration of the biobinder on the strength of granules obtained from the Borodino coal: *1* – initial granules; *2* – granules dried at 20 °C.

quettes decreases with a rise in the die temperature.

As it follows from the data shown in Fig. 5, under the compacting pressure of 100 MPa, initial coal temperature 120 °C and a 15 s exposure under pressure, an increase in the die temperature up to 350 °C causes an increase in the strength of the briquettes. For instance, with a rise in the die temperature from 300 to 350 °C the compression resistance of the briquettes increases from 10.2 to 23.7 MPa.

The resulting briquettes have the actual calorific value more than 24 MJ/kg, which is much higher than that for the initial coal (14.5 MJ/kg).

Further increase in the die temperature has only insignificant effect on the strength of the briquettes. With a rise in the die temperature from 350 to 450 °C, the strength of briquettes increases only to 26.4 MPa.

The effect of briquetting parameters on water absorption by the briquettes was investigated. It was established that the absorption of water by briquettes decreases with the die temperature increased up to 350 °C. For example, with the above-indicated briquetting parameters (pressure: 100 MPa, exposure: 15 s) an increase in the die temperature from 350 to 450 °C causes a decrease in water absorption by the briquettes from 8 to 4.5 %.

Further increase in the die temperature causes an increase in water absorption by the briquettes. With the die temperature 450 °C, the water absorption factor of the briquettes increases to 6.7 %.

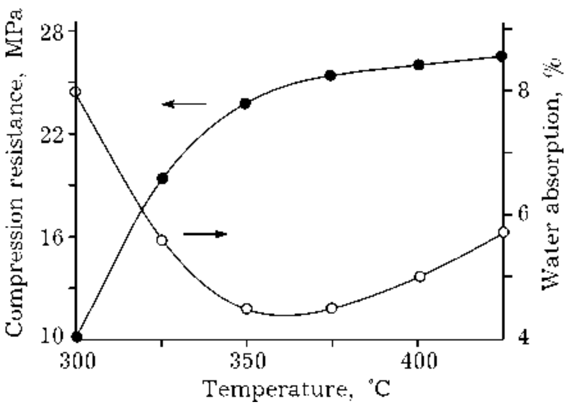

Fig. 5. Effect of temperature of the die on the strength and water absorption of the briquettes made of the Berezovo lignite.

It was established that ignition of the briquettes occurred within 50–60 s during combustion at 850 °C; they burnt without crippling. The time of complete combustion of the briquettes with a mass of 50 g was about 15 min.

Effect of pyrolysis temperature of the briquettes and granules on the properties of the resulting solid residues

The next stage of investigations included the studies of the effect of pyrolysis parameters on the physicochemical and heat characteristics of the pyrolysis products resulting from the briquettes and granules obtained using the biobinder and in the heated die.

The data on the effect of pyrolysis temperature on the specific calorific value and the content of volatile substances in the solid products are shown in Fig. 6 for the briquettes made of the Borodino lignite with the biobinder. One can see that after the treatment at 450 °C the mass fraction of volatile substances in the solid products of pyrolysis decreases to 34.7 % (in the initial coal, it is 47 %). Further rise in the pyrolysis temperature causes additional removal of the volatile substances; when the temperature of 650 °C is achieved, their content in the solid pyrolysis products decreases to 12.5 %.

Similar dependencies were obtained for the pyrolysis of granules and briquettes made of the Berezovo lignite.

The fuel related to smokeless grade is known to contain not more than 20 % mass volatile substances [4, 5]. The content of volatiles in the briquettes and granules pyrolyzed at 550–650 °C is much lower, so they can be considered as smokeless fuel. The briquettes pyrolyzed at 650 °C are characterized by the following elemental composition, mass concentration, %: C 90.7 (74.7 in the initial coal), H 2.3 (5.0 in the initial coal), O 5.9 (19–23 in the initial coal).

The data shown in Fig. 6 indicate that a substantial increase in the specific calorific value of the solid pyrolysis products occurs with an increase in temperature in comparison with the initial coal (14.5 MJ/kg). For instance, it achieves 25.8 MJ/kg at the final pyrolysis temperature 450 °C and increases further to 28.2 MJ/kg with

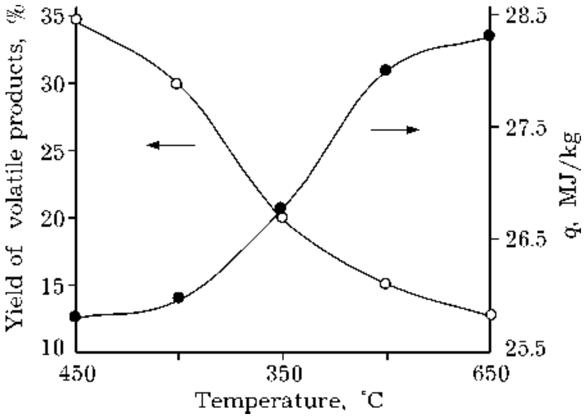

Fig. 6. The effect of pyrolysis temperature on the specific calorific value q and the content of volatile products for the briquettes obtained from the Berezovo lignite using the biobinder (with its mass fraction 30 %).

an increase in the pyrolysis temperature to 650 °C.

It was established in the experiments on the combustion of smokeless fuel at 850 °C that their ignition occurs within 95–120 s; no soot is observed during ignition and combustion of the briquettes.

CONCLUSION

Optimal conditions for obtaining high-quality briquettes and granules from the Borodino and Berezovo lignite were chosen.

In order to manufacture high-quality briquettes (compression resistance about 12 MPa and abrasion resistance about 80 %) by briquetting the Borodino lignite using the biobinder, the necessary content of the biobinder in the charge is 10 %, humidity 15–17 %, and compacting pressure 100 MPa.

In order to obtain strong granules (compression resistance up to 5.8 kg per granule) from the Borodino lignite with a plate granulator using the biocoal suspensions as a binder, the humidity of coal should be not higher than 20 %, and the concentration of the biobinder not higher than 70 %.

High-quality briquettes (compression resistance up to 23.7 MPa and water absorption 4.5 %) can be obtained in a heated die under the pressure of 100 MPa, coal temperature 120 °C and die temperature 350 °C, with the exposure of briquettes under pressure for 15 s.

The possibility to obtain smokeless fuel by the pyrolysis of briquettes and granules made of the Borodino and Berezovo lignite at a temperature not lower than 550 °C was established.

In comparison with the initial coal, smokeless fuel has a calorific value increased by a factor of 1.8–2.0 (more than 26 MJ/kg), good stability toward water and atmosphere, it is characterized by satisfactory mechanical strength and can be transported over substantial distances.

In addition to the use as a fuel, the resulting products of pyrolysis of the briquettes and granules can find wide application as carbon reducing agents.

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