ISSN 0361-5219, Solid Fuel Chemistry, 2017, Vol. 51, No. 1, pp. 48–50. © Allerton Press, Inc., 2017.
Original Russian Text © S.D. Fazylov, O.A. Nurkenov, M.A. Abdykalykov, Zh.B. Satpaeva, A.N. Zhakupova, A.Zh. Isaeva, 2017, published in Khimiya Tverdogo Topliva, 2017, No. 1, pp. 53–55.

Briquetting of Coal Siftings and Slacks in the Presence of Humates

S. D. Fazylov*, O. A. Nurkenov, M. A. Abdykalykov, Zh. B. Satpaeva, A. N. Zhakupova, and A. Zh. Isaeva**

Institute of Organic Synthesis and Coal Chemistry of the Republic of Kazakhstan, ul. Alikhanova 1, Karaganda, 470061 Kazakhstan

** e-mail: iosu8990@mail.ru*

*** e-mail: nurkenov_oral@mail.ru*

Received May 10, 2016

Abstract—Experimental data obtained in the development of a technology for the production of fuel briquettes from coal siftings and slacks are presented. The effects of the moisture content and the granulometric composition of coal components, the type and concentration of a binding agent, the compacting pressure, and the mode of solidification on the mechanical properties of fuel briquettes were studied.

DOI: 10.3103/S0361521917010049

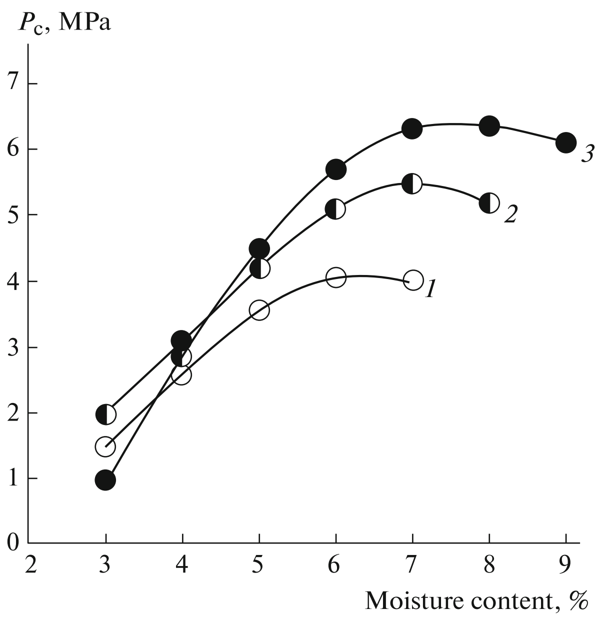
The utilization of low-grade coals of different brands (siftings, slacks, etc.), which are difficult-to-process waste coals containing to 50–70% coal matter in a number of cases, becomes an acute problem in the regions of coal production and consumption [1, 2]. The accumulation and storage of this raw material not only causes essential damage to land resources, but also it is extremely disadvantageous from an economic point of view. The use of the accumulated coal dust for the production of coal briquettes is one of the most efficient methods for the solution of this problem. The briquettes obtained from coal fines after the enrichment of coal slack have a number of advantages over the initial slack. On the combustion of coal siftings in a fuel-bed firing chamber, the efficiency of the use of the chemical energy of coal is no higher than 40–45%, whereas it can reach 70–80% on the combustion in a layer of briquettes obtained from the same coal siftings. Hence, the advantage of the use of briquettes is obvious [2–4]. The main disadvantage of the use of briquettes is related to their higher cost, as compared with siftings and slacks, due to the costs of briquetting and the use of binding agents. At the same time, the reserves of waste coals are enormous, but their combustion in a fine-grained form is difficult to perform or, more frequently, practically impossible. Thus, the development of a briquetting technology for fine coals, coke breeze, slacks, etc., is a problem of considerable current interest.

In the selection of the optimum granulometric composition of a charge mixture for the production of briquettes, the key factor is the closest packing with a minimum quantity of voids and cavities, which can be achieved with the use of binding agents. Many attempts at using various materials (cement, lime, gypsum, molasses, lignosulfonates, etc.) for the briquetting of coals are well known from the literature [3–5]. Among these binding materials, coal-tar pitch and petroleum bitumen have found the widest use for the briquetting of coal fines. The briquettes prepared with the use of the above binding agents possess high compression and breaking strengths; however, carcinogenic substances are released on the combustion of these briquettes to restrict the use of such briquettes in boiler rooms. In this context, the use of humates (humic acid salts) in the production of fuel briquettes is very interesting. Humates (sodium humate, ammonium humate, calcium humate, etc.) are multipurpose plasticizer reagents with stabilizing and fluidizing actions [6, 7].

In addition to ecological compatibility, the briquette products should have a low cost price and remain a competitive fuel on the market of energy resources. Current technology includes adequately developed and widely used processes for the briquetting of coals. Extrusion briquetting with the use of a binding agent is the most reasonable and technically sound process in terms of reducing the cost of the briquettes and increasing their manufacturability.

The aim of this work was to study the briquetting of coal-slack charge mixtures in the presence of the following three binding agents: sodium and calcium humates and a humate silicate, which were obtained by alkaline extraction from oxidized coals of the Maikube deposit (Kazakhstan).

In this study, coal siftings of the K12 grade (Karaganda coal field) and coal slack (waste coal with an ash content of 34.5% and a total moisture content of



Dependence of the strength of a finished crude briquette on the moisture content and binding agent concentration. Consumption of sodium humate (wt %): (*1*) 2.0, (*2*) 3.0, and (*3*) 6.0.

12.1%) were used as test materials. The screen analysis of the coal slack showed that, in the grain composition of the coal slack with particle sizes of 0–3 mm, the concentration of fractions of 1–2 and 0–1 mm was 45–60%, and that of particles greater than 3 mm was no higher than 8–10%. The K12 coal siftings had the following characteristics: ash content, 19.3%; total moisture, 10.4–11.6%; yield of volatile substances, 25.6%; weight fraction of sulfur, 0.7%; low heat value, 5400 kcal/kg; and high heat value, 7300 kcal/kg.

The preparation of a coal charge mixture plays a significant role in the process of briquetting. The principle of the selection of a mixture of particles with different sizes and an optimum bulk weight is based on the theory of the closest packing of grains. With an incorrectly selected coal-size composition of the charge mixture or its poor preparation, the space between coal grains is filled with a binding agent or its mixture with small coal grains to disrupt necessary bonds between the coal grains; because of this, it is impossible to obtain briquettes with a required strength.

As follows from the literature data [4–7], the maximum strength of briquettes it is reached when a particle size distribution approaches the granulometric composition corresponding to the greatest packing density of coal grains. In actual practice, it is not always possible to maintain a constant optimum grain composition. As a result of the studies, the following granulometric composition of a charge mixture for briquetting was determined: 3–5 mm, 5–8%; 1–3 mm, 27–36%; and 0–1 mm, 48–55%. The charge mixture with the optimum granulometric composition at a sifting to slack ratio of 8 : 2 and with different moisture contents was thoroughly mixed with a binding agent to obtain homogeneous mass.

The effect of the consumption of a binding agent on the strength of a finished briquette was studied at the first stage. Miniature cylindrical briquettes with a diameter of 25 mm and a height of 13–15 mm were made in order to determine an optimum binding agent consumption. In this case, the compacting pressure was constant (20 MPa). The charge mixture was extruded with the aid of a hydraulic press (PGR-10). The binding agent consumption was varied in a range from 1 to 12% on a charge weight basis. With the use of a humate silicate solution in a concentration higher than 5%, the resulting charge mixture hardened rapidly, and briquettes with calcium humate exhibited variable characteristics. In connection with this, it was expedient to select an optimum binding agent consumption based on the necessary and sufficient strength of a briquette and the cost of its production. Sodium humate in different concentrations was used as a binding agent in the subsequent tests. The strength of a finished briquette was the principal optimization criterion. For testing the repeatability of experimental data, seven briquettes per each experimental point were prepared in accordance with GOST [State Standard] 21289-75. The strengths of briquettes in the experiments with the test binding agent coincided to within 3%.

The crude briquettes obtained after extrusion were supplied to a drying oven at a temperature of 105°C for 1 h in order to study changes in the strength of a crude briquette as functions of the moisture content of the charge mixture and of the consumption of the binding agent. The briquette samples cooled to room temperature were subjected to uniaxial compression for measuring the pressure of destruction. The figure shows averaged data on the strength characteristics of briquettes determined by a compression method; whence it follows that the strength of a briquette exponentially increased to a maximum with the binding agent consumption (from 2 to 6%) and the moisture content of a crude briquette. It is likely that a further increase in the consumption of the binding agent is unreasonable because it may lead to an increase in the cost of the final products. For each particular binding agent consumption, there is an optimum moisture content of the charge mixture at which a crude briquette reached a maximum strength.

According to the literature data [5, 8], the formation of the stable structure of a fuel briquette occurs in four stages. At the first stage, the surface of coal particles is wetted with a binding agent. The second stage is characterized by the appearance of the maximum adhesive capacity of the mixture and the formation of coagulation structures. At the third stage, the interaction of the binding agent and coal particles strengthens as a result of the application of compacting pressure. At the fourth stage, strengthening accompanied by the conversion of coagulation structures into condensation–crystallization structures occurs to ensure the mechanical strength of fuel briquettes.

Fundamental technical characteristics of coal briquettes from the test batch

Charge mixture composition, wt %		Briquette quality characteristics, %						
siftings	slack	R_{cbr}	R_{true}	A^d	W	V^{daf}	Q_i^r, kcal/kg	Q_s^{daf}, kcal/kg
90	10	83.5	77.2	32.4	3.84	38.3	4324	6332
80	20	86.2	82.5	30.2	3.85	36.5	4561	7043
70	30	86.4	82.7	34.6	3.84	36.3	4682	7128
60	40	85.7	83.4	34.5	3.79	37.0	4574	6531
50	50	86.4	83.5	31.2	3.73	36.8	4355	6450

At the second stage of this study, a series of experiments was carried out with the 30-g cylindrical briquettes 25 mm in diameter and 45–50 mm in height. Various coal siftings–slack (wt %) compositions for briquetting were prepared; the moisture content of the charge mixture was 17–18%. The briquetting was performed on a PSh 1000 screw extruder at a compacting pressure of 275 kgf/cm^2 (27.5 MPa). The granulometric composition of the charge mixture corresponded to the parameters specified at the first stage of the experiments. A solution of sodium humate (6–8 wt %) was used as a binding agent. The strength of the briquettes formed was sufficient for their transportation to the site of strengthening and for storage without destruction. The strengthening of briquettes can be performed both under natural hardening conditions at an ambient air temperature of 18–20°C and a relative humidity of 55–60% and with forced drying. To intensify structurization processes, the briquettes were heat treated under the following conditions: temperature, 105–110°C; exposure time, 1 h; and air cooling. The results of the tests of briquettes after heat treatment are given below (see the table).

According to the results of the studies, the mechanical strength of briquettes was improved as the slack content of the charge mixture was increased to 50 wt %. However, in this case, briquette production on an extruding press led to technological difficulties because of superfluous stickiness and moisture content of the charge mixture. The resulting briquettes were moisture-proof, as evidenced by small water absorption of 3.7–3.8% (with a normative value of no greater than 4.0%). Briquettes were ignited by burning firewood (the inflammation of briquettes occurred within 110–113 s); the combustion occurred without producing an odor, and the ash residue of a powdered structure was not caked. The heat resistance of the briquettes is characterized as incandescent; in the course of combustion, they did not crumble and retained their shape.

Thus, the combined briquetting of the small fractions of coal siftings with coal slack from a coal-preparation plant makes it possible to obtain briquettes with an optimum mechanical strength. The above briquetting technology ensures the uniformity and stability of the quality characteristics of coal fuel composites. The currently available methods of the thermal briquetting, pelletizing, and granulation of combustible solid wastes are expensive and labor-intensive, and they impose requirements on the quality of source materials; therefore, the extrusion briquetting technology is the most promising and multipurpose process for these raw materials. The composition and formulation for the preparation of fuel briquettes can be changed depending on the nature of source materials and the designation of fuel.

Thus, the combined briquetting of the small fractions of coal siftings with coal slack from a coal-preparation plant makes it possible to obtain briquettes with an optimum mechanical strength. The above briquetting technology ensures the uniformity and stability of the quality characteristics of coal fuel composites. The currently available methods of the thermal briquetting, pelletizing, and granulation of combustible solid wastes are expensive and labor-intensive, and they impose requirements on the quality of source materials; therefore, the extrusion briquetting technology is the most promising and multipurpose process for these raw materials. The composition and formulation for the preparation of fuel briquettes can be changed depending on the nature of source materials and the designation of fuel.

REFERENCES

1. Maloletnev, A.S., Mazneva, O.A., and Naumov, K.I., *Khim. Tverd. Topl.* (Moscow), 2012, no. 2, p. 47.
2. Golovin, G.S., Rode, V.V., Maloletnev, A.S., and Lunin, V.V., *Khim. Tverd. Topl.* (Moscow), 2001, no. 4, p. 11.
3. Shuvalov, Yu.V., Tarasov, Yu.D., and Nikulin, A.N., *Gorn. Inform.-Analit. Byull.*, 2011, no. 8, p. 243.
4. Buravchuk, N.I. and Gur'yanova, O.V., *Khim. Tverd. Topl.* (Moscow), 2014, no. 4, p. 47.
5. Elishevich, A.T., *Briketirovanie uglya so svyazuyushchimi (Coal Briquetting with Binding Agents)*, Moscow: Nedra, 1972.
6. Papin, A.V., Zaostrovskii, A.N., Solodov G.A., Murko V.I., Zherebtsov S.I., *Vestn. KuzGTU*, 2003, no. 4, p. 96.
7. Evstifeev, E.N., *Mezhd. Zh. Prikl. Fundam. Issled.*, 2011, no. 6, p. 51.
8. Rode, V.V. and Ryzhkov, O.G., *Khim. Tverd. Topl.* (Moscow), 1994, no. 6, p. 43.

Translated by V. Makhlyarchuk