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# Production of Carbon Briquetted Fuel from the Coals of Kansk-Achinsk Basin by Means of Hot Pressing

**Pyotr N. Kuznetsov[a]*, Anatoly S. Maloletnev[b] and Svetlana M. Kolesnikova[a]**
*[a] Institute of Chemistry and Chemical Technology, SB RAS, 42 Karl Marx st., Krasnoyarsk, 660049 Russia*
*[b] Institute of Fossil Fuels, 29 Lenin pr., Moscow, 119071 Russia [1]*

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*The paper presents the results of the research on thermobriquetting of dense brown and gaseous coals from Kansk-Achinsk basin, brown and gaseous coal mixtures with no binding agent as well as a mixture of brown coal with hydrolyzed lignin as a binding agent.*
*The heating values of the products were shown to increase 1,3-1,5 times in comparison with the raw coals and the volatile yields causing black smoke decrease by 11-13 %. Most efficient, strong moisture-proof briquettes with the heating value of 25,50 MJ/kg were produced of the mixture of the B3 brown and gaseous coals. The addition of lignin to the brown coal allowed lowering the pressing temperature from 380-400 °C to 200-250 °C, thus improving the reliability of the press operation.*

*Key words: coal, lignin, coal briquettes, binding agent, thermobriquetting.*

## Introduction

Use of mining combines, rotor excavators and scraper conveyors as well as transporting and loading machines and mechanisms in mines and strip mines can lead to large amount of coal crank. It can cause some problems in storage and transportation of this fuel, worsens its ecological characteristics. The largest amount of crank is produced of brown coals with low strength. The additional crank is produced during its storage because of its disposition to weathering and spontaneous inflammation. The fuel with the large content of fine fractions can be utilized successfully by the thermal power stations with the powdered fuel combustion system but is not good enough for household use.

One of the efficient ways to improve utilization of brown coals is manufacturing of high quality briquettes and rolled briquettes [1-4]. The raw material base for production of high quality fuel, briquettes in particular, is located in Kansk-Achinsk brown coal basin (KAB) with the coals of low mining cost and more ecologically friendly in comparison with other coals thanks to lower sulphur and nitrogen contents as well as the content of mineral substances, including toxic ones [5, 6]. The basin also has reserves of dense high-energy gaseous coals.

* Corresponding author E-mail address: kpn@icct.ru

KAB coals are mostly of B2 dense brown coals type, not good for briquetting without binding agent. The technology based on the application of petroleum bitumen as a binding agent for brown coal briquetteting was developed by the Moscow Institute of Solid Fuel Upgrading. The briquette factory in Kansk-Achinsk basin manufactures brown coal briquettes using this technology. The main disadvantages of the technology are high cost of bitumen (30 % of the raw coal cost) and much black smoke and high toxic volatile yield during briquette combustion.

The Institute of Fossil Fuels carried out a research on KAB brown coals briquetting with no binding agents. The technology of hot pressing which has been developed is based on the ability of brown coal to soften at a high temperature due to generation of some plastic matter [7 - 9]. The crushed raw coal is dried by a gaseous heat-carrying agent in a turbulence drying chamber and after short thermal aging is passed to the presses where, under the pressure and temperature of 380-400 °C, the coal is compressed into briquettes without the addition of any binding agent. Bonding of coal in briquettes depends on the pressure of the press, temperature and coal properties. The technology has been applied to the coals of B2 type at Berezov, Borodino, Aban, Itat and Urjupinsk deposits of KAB. The produced thermobriquettes have much higher heating values in comparison with the raw coals (25,50 MJ/kg vs. 15-16 MJ/kg), are stronger and more moisture-proof in storage, exhaust less black under combustion (volatile yield causing black smoke is 8-12 % less), emit less gum substances.

This paper presents the results of experimental research on thermobriquetting of more dense B3 type brown coal and of low-caking gaseous coal from KAB and their mixtures as well as of brown coal with the additives of hydrolyzed lignin as a binding agent.

## Experimental

The brown coal from Latyntsev deposit and gaseous coal from Sayan-Partizansky deposit of KAB and hydrolyzed lignin from Krasnoyarsk Biochemical plant were used as the raw materials. Their ultimate and proximate analysis data are given in Table 1.

The tests on thermobriquetting were carried out on laboratory and pilot facilities. For laboratory tests, the raw crushed coal with the particle sizes of less than 1 mm was loaded into the press matrix preheated to the necessary temperature with the rate of 1,5° C/min, subjected to heat ageing, and then hot coal was pressurized by hydraulic press. In pilot tests, the crushed coal was loaded into the bin and with the help of worm feeder passed to the turbulence chamber, a gaseous heating agent from the furnace being fed simultaneously. After being heated to the necessary temperature the coal was passed to the cyclone separation to remove dust, after that it was transported to the heat ageing for 0,5-4 min, and then to the stamping press. According to the maintenance experience the optimal pressure of 75 MPa was chosen, and treatment temperature was varied from 200 to 400 °C.

## Results and discussion

The results of the tests on thermobriquetting of brown and gaseous coals depending on the treatment temperature are presented in Tables 2 and 3. The substantial increase in mechanical strength from 1,0 to 4,5 MPa, the decrease in volatile yield from 46,1 to 36,6 %, as well as moisture absorption from 5,6 до 3,8 % and increase in heating value from 22,90 to 23,22 MJ/kg were observed under the increase of temperature from 300 to 400 °C. In comparison with the raw coal the volatile yields causing black smoke decreased by 11-13 %, heating values increased from 16,51 to 23,22-23,37 MJ/kg, i. e. almost 1.5 times.

Table 1. Proximate and ultimate analysis data for raw material

| Coal | Ash $A^d$, wt % | Volatile yield $V^{daf}$, % | wt % on daf coal | | | | | Heating value, MJ/kg |
|---|---|---|---|---|---|---|---|---|
| | | | C | H | S | N | O | |
| Brown coal | 16,0 | 47,4 | 73,5 | 5,2 | 1,1 | 0,4 | 20,3 | 16,51 |
| Gaseous coal | 14,1 | 43,5 | 78,5 | 5,9 | 1,5 | 1,4 | 12,7 | 19,69 |
| Hydrolyzed lignin | 2,4 | 63,4 | 63,1 | 6,5 | 1,3 | 0,7 | 28,4 | - |

Table 2. Thermobriquetting of brown coal from Latyntsev deposit

| Temperature, °C | Volatile yield $V^{daf}$, wt % | Mechanical compression strength, MPa | Heating value, MJ/kg | Moister absorption, wt % |
|---|---|---|---|---|
| 300 | 46,1 | 1,0 | 22,90 | 5,6 |
| 350 | 42,0 | 1,4 | 22,59 | 4,5 |
| 380 | 36,6 | 4,5 | 23,22 | 4,3 |
| 400 | 34,1 | 4,6 | 23,37 | 3,8 |

Table 3. Thermobriquetting of gaseous coal from Sayan-Partizansky deposit

| Temperature, °C | Volatile yield $V^{daf}$, % | Mechanical strength, MPa | Heating value, MJ/kg | Moister absorption, wt % |
|---|---|---|---|---|
| 300 | 40,1 | 3,7 | 25,87 | 2,3 |
| 350 | 39,5 | 4,3 | 26,13 | 3,3 |
| 380 | 36,5 | 5,2 | 26,25 | 3,2 |
| 380* | 36,1 | 11,1 | 25,50 | 3,5 |

*Brown and gaseous coals' mixture with the ratio of 1:1

In case of gaseous coal, the temperature increase leads to the increase in briquette's strength from 3,7 to 5,2 MPa and to the decrease in volatile yield from 40,1 to 36,5 % (Table 3). Moisture absorption is 2,3-3,2 %, heating value ranges from 25,87 to 26,25 MJ/kg. Consequently, in comparison with the raw coal, heating value of briquettes increased 1,3 times, and volatile yield decreased by 13,0 %.

The composition of brown and gaseous coal thermobriquettes produced is as follows, wt. %: $C^{daf}$ 75,4 and 81,5; $H^{daf}$ 4,7 and 4,6; $S^d$ 1,0 and 1,6; $N^{daf}$ 0,5 and 1,5 %, respectively.

It should be noted that the gaseous coal from Sayan-Partizansky deposit is of low-coking type with the thickness of plastic layer about 9 mm. The generation of substantial volume of plastic matter caused some problems in the press operation due to coking. This disadvantage was overcome by its pressing in the mixture with brown coal playing the role of a thinning additive. It was found that the thermobriquetting of the coals mixture was smooth and the pressing equipment operated in the reliable way, the manufactured briquettes being strong, stronger than those produced of the original coals. Under the heating temperature of 380 °C for the mixture with 1:1 ratio, the strength reached 11,1 MPa, while moister absorption and heating value were 3.5 % and 25,5 MJ/kg, respectively.

Hydrolyzed lignin is known to yield a certain volume of plastic matter at the temperature between 200 and 250 °C [10,11]. This property was used to improve the plastic behavior of dense brown coal on thermopressing by mixing with a hydrolyzed lignin (instead of petroleum bitumen) [12,13].

The lignin content in the mixture was varied from 15 to 40 wt. %, and the pressing temperature - from 200 to 300 °C. The lignin was preliminary dried till the 15 % humidity, after that it was crushed and dried again till residual humidity of 8 %. In lab tests, the prepared mixture of brown coal and lignin with the particles less than 1 mm was loaded into a preheated pressing form which was placed into a preheated furnace and exposed to isothermal ageing, and then the hot mixture was pressed.

The coal-lignin briquettes produced by this technology were mechanically very strong. Their moisture-proof property to certain extent depended on the briquetting conditions and batch composition (Table 4). Improved briquettes with increased moister-proof properties were produced under rather low briquetting temperatures of 200-250 °C. With the temperature increase the tendency to moister absorption increase was observed. Under 200-250 °C the most moister-proof briquettes were produced under thermal ageing time of 10-15 min.

Under briquetting temperature of 200 °C, the increase in lignin content in the mixture from 15 to 40 % improved the moister-proof property from 10,1 to 4,1 % (Table 5).

Table 4. Moister resistance of coal-lignin briquettes depending on the temperature and the time of thermal ageing (coal:lignin ratio is 70:30, pressing pressure is 100 MPa)

| Time of thermal ageing, min | Briquetting temperature | | |
|---|---|---|---|
| | 200 °C | 250 °C | 300 °C |
| | Moister absorption, wt % | | |
| 5 | 11,0 | 10,3 | 10,2 |
| 10 | 7,4 | 6,5 | 15,8 |
| 15 | 6,1 | 7,9 | 17,3 |
| 20 | 10,3 | 12,7 | 18,7 |

Table 5. Moister resistance of briquettes depending on the coal-lignin ratio

| Coal-lignin ratio, wt | 85/15 | 80/20 | 70/30 | 60/40 |
|---|---|---|---|---|
| Moister absorption, wt % | 10,2 | 6,4 | 5,2 | 4,1 |

The data obtained have demonstrated that lignin additives allow dense brown coal being briquetted under rather low temperature of 200-300 °C producing reasonably moister-proof briquettes with a high mechanical strength. The coal-lignin briquette manufacturing makes it possible to produce high-energy graded fuel for household use and at the same time, to use toxic lignin waste.

## Conclusions

1. The highly moister-proof briquettes with high mechanical strength, high energy and low volatile yield were produced of B3 dense brown coal from Latyntsev deposit and from gaseous coal from Sayan-Partizansky deposit by means of hot pressing. The heating value of the produced briquettes in comparison with the raw coals was 1,3-1,5 times higher and volatile yield causing black smoke decreased by 11-13 %.

2. The calorific briquettes of the highest mechanical strength up to 11,1 MPa were produced of the mixture of gaseous and brown coals.

3. Adding hydrolyzed lignin as a binding agent allows lowering the pressing temperature from 380-400 $^{o}$C to 200-250 $^{o}$C, thus increasing the reliability of the press operation.

4. The thermobriquettes are more ecologically safe than ungraded coals under transportation, storing and combustion for semi-industrial and household uses.

5. The briquette manufacture technology based on hot pressing is all-purpose and flexible and can be applied to the upgrading of coals of different types.

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