Upgrading of qualitative characteristics of Yakutia brown coals

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Abstract. In Yakutia the fuel-and-energy balance involves low-grade brown coals originated from Kangalas, Kirov and Kempendyay deposits. The techniques to improve the efficiency of utilization and conservation of these coals involve classification of coals and burning of coarse-size products, enrichment, and briquetting of fine coal products. The last technique permits to upgrade the poor-grade coals of low demand and to produce the full-value fuel coal, convenient for transportation, long storage and effective combustion. The experimental results are given on the agglomeration of Kirov brown coal by briquetting with the introduction of polyethylene crumbs into the briquetting blend. This addition promotes 20 % increase in combustion heat as compared to this parameter for the original coal. The researchers propose the technological scheme for classification, preparation, follow-on briquetting of brown coals. The urgency of a local classification-and-briquetting plant is pointed out.

1. Introduction
Black coals, supplied for public-and-living needs to Yakutia central and northern regions are mined at Zyryansk, Jabariki-Khainsk and Kharbalakh deposits. The geographical location of these deposits does not enable to provide an economically effective delivery of these coals to all the regions of the Republic. High transportation costs are the limiting factor for long-distance coal transportation and explain the need in availability of small brown coal plants in remote territories with regard to Kirov, Kempendyay and Kangalass open-pit coal mines.

In Republic of Sakha (Yakutia) coal is one of main energy resources for public-and-living needs (Table 1).

| Parameter                | Coal   | Gas    | Oil    | Gas condensate | Fuel wood |
|--------------------------|--------|--------|--------|----------------|-----------|
| Fuel volume, t.c.t. unit | 1115361| 1027669| 892450 | 16345          | 4546      |
| Share, %                 | 49.5   | 45.6   | 4.0    | 0.7            | 0.2       |

Source: Database GKC SR(Ya) dated 01.01.2018.

In the heat tariff structure the fuel component plays an important role with consideration for delivery and storage expenditures and in average amounts to 60 %. In hard-to-reach areas the coal expenditures reach 15-20%, the rest expenditures are water and truck-transportation, storage and rehandling. The situation is complicated by focal character of population as 75 thousand people live in
104 undeveloped locations of 1.6 Mkm² in total area, the need is obvious to maintain great number, namely, more than 140 boiler-house plants, including 69 plants operating on coal fuel and diesel power stations [1, 2].

2. Analysis of hard briquettes production

The analysis of the cost per one ton of standard fuel in the structure of fuel-energy resources utilized for housing services in Republic of Sakha (Ya) reveals that the coal remains the competitive and promising natural resource for perspective utilization and high-level processing for a number of plants, in spite of constraining price control for gas, oil, boiler fuel.

Comparative prices for fuel-and-energy resources with the calorific efficiency data (fuel type/ cost in t.c.t. units) are reported in Table 2.

| Table 2. Grade and cost of energy resources of Sakha Republic (Yakutia) |
| Fuel type | Coal rank | Average operative calorific power, kcal/cub m | Price (2017) for fuel, actual RUB/t.c.t unit |
|-----------|-----------|---------------------------------------------|---------------------------------------------|
| Neryungry open-pit mine, Yakutugol Co. | Coke      | 5680                                        | 2 123                                       |
| Jebariky-Khaya mine, Yakutugol Co.* | Long-flame | 5400                                        | 2 691                                       |
| Kangalass open-pit mine, Yakutugol Co.* | Brown     | 3490                                        | 1 167                                       |
| Zyroynsky open-pit mine Closed JSCo.* | Fat       | 6100                                        | 3 062                                       |
| Telen Co.* | Long-flame | 4900                                        | 1 627                                       |
| Suntarzeolite Co.* | Brown     | 3272                                        | 1 111                                       |
| Kirov coal open-pit mine Co.* | Brown     | 3321                                        | 1 454                                       |
| Gasocondensate Co. “YaTEK” |              | 10000                                       | 18 081                                      |
| Oil Surgutneftegas Co. |             | 10127,9                                     | 18 141                                      |
| Oil Irelyakhneft Co. |             | 9860                                        | 14 617                                      |

* database GKC SR (Ya)

In the Republic of Sakha (Yakutia), the fuel-and-energy balance partially involves low-grade brown coals from the Lena Coal Basin. These coals are of certain significance for heat power production in Central and Western regions. However, higher ash content, high humidity and oxidation capacity of brown coal, underdeveloped industrial infrastructure in brown coal mining areas negatively affect consumer properties of brown coal and its price as a consequence.

Therewith, in spite of appreciable brown coal reserves in Kangalass, Kirov, and Kempendyay deposits the heat-power plants in Nyurbinsky, Amginsky, Olekminsky, and Suntarsky regions operate on coal delivered from Jebarik-Khaya black coal deposit. No consideration is given to the fact that in practice the use of run-of-mine coals transported at distance of more than 1000 km does not make economic sense for a consumer. The consumer can meet one and the same demand for heat by combustion of close-to-alternative fuel types.

Based on the analytical data on the fuel briquetting techniques [3– 6], the researchers of IGDS SB RAS conducted the feasibility study of brown coal briquetting with a binding agent and the follow-on evaluation of appropriateness to build a local briquette-classification plant on the basis of Kirov open-pit mine in Nyurbinsky region, Republic of Sakha (Yakutia).

The coal specimens sampled at the open-pit were ground at a jaw mill down to two size fractions. Domestic polyethylene wastes were used as a binding agent in laboratory experiments. The domestic polyethylene wastes were ground down to less than 2 mm in coarseness in amount of 6-7 % of the dry coal mass. In the drying cupboard a matrix with a material to be briquetted was preliminarily heated and the temperature was maintained within 160–170 °C. The blend was heated up to 130 °C. Thermopair, installed in the center of the matrix with the material to be briquetted inside of the drying cupboard, was employed to measure heating temperature in the blend of coal and polyethylene cips.
Eight matrices of 40 mm in diameter were stuffed with the blend for briquetting and mounted in the experimental drying cupboard. Thermal treatment of the study blends of coal with polyethylene crumbs was performed without isothermal curing. Briquetting of heated blends is performed under pressure of 78 MPa at P-10 press. The compressive tests of prepared briquettes were carried out 24 hours later after briquetting.

Heating of the ground polyethylene in the cupboard showed that polyethylene softens at temperature 90-100 °C. The melting temperature is 103–110 °C for the low-pressure polyethylene, and 124–137 °C for high-pressure polyethylene. Polyethylene degrades under heating in the air at 80 °C. It is actually harmless, with no emission of toxic species under combustion.

It was established in the earlier research that the maximum mechanical strength of briquettes is gained in briquetting of coal–polyethylene chips blend under preliminary heating up to 130-140 °C (Table 3).

The analysis of experimental data enabled to set forth the following statement: the maximum possible strength of produced briquettes is gained for coal of less than 2 mm in size and polyethylene chips content about 7%. Thereto compressive strength of briquettes is 9.16 MPa, it being much higher than standard mechanical strength according to GOST 8584-76, which runs that mechanical compressive strength of brown-coal briquettes must be at least 7.8 MPa. It is also important to point out that the new-produced briquettes exhibit specific insufficient water adsorption they are water resistant and lose only 16.7% of their mechanical strength in 2 hours of their being in water.

Table 3. Experimental investigation into briquetting of Kirov brown coal with polyethylene chips as a binding agent

| Coal size, mm | Polyethylene content in blend, % | Compressive strength of briquettes, MPa | Water adsorption by briquettes, % | Residual hardness of briquettes, MPa / water resistance, % |
|---------------|----------------------------------|----------------------------------------|----------------------------------|----------------------------------------------------------|
| less than 2   | 6                                | 6.38                                   | 16.25                            | 2.91 / 45.6                                              |
| less than 6   | 6                                | 7.99                                   | 9.38                             | 5.58 / 69.8                                              |
| less than 2   | 7                                | 9.16                                   | 4.5                              | 7.63 / 83.3                                              |
| less than 6   | 7                                | 7.82                                   | 9.2                              | 6.32 / 84.2                                              |

The combustion heat of the fuel is assessed under GOST 147-95 “Solid fuel. Process for determination of upmost combustion heat and calculation of the lowest combustion heat”. The process is based on complete combustion of a test fuel mass in a calorimetric bomb at exothermal and adiabatic modes at the constant volume in the compressed air atmosphere and measurement of temperature rise of a calorimetric vessel at the expense of heat emitted by burned fuel and auxiliary matter with consideration for formation of aqueous solutions of nitric acid and sulphuric acid under experimental conditions. The average value of the upmost combustion heat (Qas) is 5439 kcal/kg, the lowest combustion heat (Qai) – 5207 kcal/kg, it is more than 20% higher than the combustion heat value for the original coal.

To conclude, the briquetting of Kirov brown coal with binding polyethylene chips of less than 2 mm in size and preliminary heating of the test blend up to 130 °C allows production of hard water-resistant briquettes exhibiting the higher combustion heat.

The present research results served the basis to work out and to propose a flowsheet for classification and processing of brown coal with briquetting (Figure 1). The original brown coal is subjected to crushing at RD-MDV-900 with follow-on screening at SMD-113. Next, -20 mm fraction is recrushed at DKD-300 with screening. Fraction of -2 mm is treated at POS-2000 semi-industrial pneumoseparator. Briquetting with polyethylene chips as a binding agent softened at 130-140 °C. Briquetting proceeds at PBV-500/200 100P press. The ready-made fuel briquettes are stored at special storage facilities.
3. Conclusions
Based on analytical data and laboratory tests it is demonstrated a feasibility to utilize Kirov brown coal to produce hard briquettes with the use of ground domestic wastes, namely, polyethylene chips. The proposed principal flowsheet of a briquetting-classification plant can be considered as the basis for justification of necessity, expediency, economic and ecological efficiency of this plant. The objective is to improve energy security and reliability of high-grade fuel supply to remote territories, simplification of coal delivery to consumers, reduction in quantitative and qualitative coal loss, increase in boiler performance.

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