Technology of waste coal processing used for fuel production

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Abstract. The technology and equipment were developed for the preparation and burning of suspension coal-water slurry fuel in boiler plants and heat power plants, obtained on the basis of fine dispersed waste coal (filter cakes) of processing plants. The studies were conducted on the basis of filter cakes from “Mine Komsomolets” and “Mine n.a. S.M. Kirov”. It is shown that on the basis of these wastes it is possible to prepare suspension coal-water slurry fuel with a solid content up to 56-60%, the required structural and rheological characteristics and lower heat value up to 13 MJ/kg. On the basis of the research results, a working draft for the creation of a pilot technological complex, processing waste coal with the production of coal-water slurry fuel and its combustion in a boiler plant, was developed.

1. Introduction

The features of the technological schemes of modern coal-processing plants (PPs) in Russia are the use of a closed water-sludge cycle, which eliminates the discharge of sludge waters from the factory into external sumps and hydraulic dumps, and the absence of thermal drying of small classes of coal due to their more effective mechanical dehydration in precipitation-filtering centrifuges – decanters and vacuum filters of various designs.

It was supposed to solve two problems: reduction of the cost of coal preparation process and improvement of its environmental friendliness. However, in fact, as experience of the PP operation shows, none of these problems has been fully resolved. In fact, in the factories, unprocessed coal sludge and waste coal with a particle size up to 300 (3000) µm thicken in radial thickeners. The thickened product is then sent to belt or chamber filter presses for dewatering.

The flocculants of anionic and cationic types are used to intensify the processes of thickening, clarification or filtering, the flow rate of which is up to 460 g/t of solid phase. In this process, a significant proportion of dissolved flocculants is contained in the liquid phase and on the surface of the solids of the residue (filter cake). Calculations show that one tonne of filter cake contains up to 450 g of extremely toxic flocculants, the withdrawal of which outside the factory is unacceptable [1-5].

However, at present, filter cake with particle size 0-3000 µm, content of grade 0-100 µm up to 90%, moisture content of 30-45% and ash content 23-62% cannot be added to a commercial product, it is not used as an independent product and is sent to the dump together with a large rock. As a result, the environment is significantly polluted and up to 10-12% of the processed coal is lost. In addition, the...
circulating water is saturated with residual flocculants, which disrupt the coal beneficiation process [6-10].

As one of the solutions to this problem, it is proposed to use the technology of producing WCF from the filter cake and, if necessary (high ash content of the filter cake), industrial product and small grades of coal (screening). The resulting fuel can be burned in specialized boilers to produce thermal and (or) electric energy [11-15].

The purpose of the research is the creation of a technological complex for the processing of finely dispersed waste coal by preparing and burning suspension coal fuel from the filter cake of the processing plants of “SUEK-Kuzbass” JSC, which makes it possible to reduce:

- storage volumes of toxic waste coal in the areas where processing plants are located;
- up to 30% emissions of nitrogen oxides in the flue gases of heat power plants and boiler rooms;
- the cost of generating heat and power energy by reducing the cost of the fuel component.

In the course of work, the following tasks were solved:

- Determination of the composition and consumption of plasticizing additives to obtain water-coal fuel (WCF);
- Development of regulations for the preparation and burning of WCF pilot batches;
- Determination of the level of harmful emissions from the burning of WCF pilot batches;
- Development of the technological scheme of a pilot complex for the preparation and burning of WCF.

2. Feedstock

The samples of the filter cake, two tonnes each, were delivered to study the possibility of preparing WCF on the basis of finely dispersed waste coal from “Mine Komsomolets” (sample 1) and “Mine n.a. S.M. Kirov” (sample 2). Samples delivered to the testing bench of KuzSTU were analyzed in the coal chemistry laboratory. Qualitative characteristics of the studied samples are shown in table 1.

| Table 1. Samples specifications. |
|-------------------------------|
| Indicator                        | PP of “Mine Komsomolets” | PP of “Mine n.a. S.M. Kirov” |
| Total moisture, %                | Sample No. 1  | Sample No. 2  |
| Ash content (on dry fuel basis), % | 35.0         | 40.6          |
| Release of volatile substances (on dry ash free fuel basis), % | 28.7 | 40.8 |
| Total sulfur (on dry fuel basis), % | 43.0 | 41.9 |
| Higher calorific value (on dry fuel basis), MJ | 0.5  | 0.15 |
| Lower heat value, MJ             | 13.75        | 11.8          |
| Granulometric composition, mm    |                          |
| 0.250 – 3.0:                     | 7.1           | 5.5           |
| 0.071 – 0.250                    | 16.9          | 22.0          |
| - 0.071                          | 76.0          | 72.5          |
| Total                            | 100.0         | 100.0         |

Analysis of the data in table 1 showed that the moisture content of the filter cake samples was relatively high – \(W_{r} = 35.0 \text{–} 40.6\%\). The ash content of the filter cake can vary over a wide range of values – from less than 30% to more than 40%. The granulometric composition of the filter cake from PP of “Mine Komsomolets” and “Mine n.a. S.M. Kirov” included fineness classes up to 3.0 mm.
3. The method of obtaining a suspension coal fuel

Filter cake is a semi-finished product for WCF production without additional grinding. At the same time, the technological characteristics of this fuel allow it to be burned together with traditional fuel in standard pulverized coal boiler units. Rheological and thermophysical characteristics were determined using standard methods.

The purpose of the work was to select the optimal additive option based on the analysis of the values of the main structural and rheological characteristics of the prepared WCF.

During the experimental work, the type of plasticizing additive and its consumption (0.3%), the mass fraction of the solid phase in the finished fuel (57.0%) was determined.

Table 2 shows the structural-rheological and thermophysical indicators of the experimental batches of WCF.

Table 2. Characteristics of the prepared pilot batches of WCF.

| Parameter                          | Mine n.a. S. M. Kirov | “Mine Komsomolets” |
|------------------------------------|-----------------------|--------------------|
| Ash content \( A^d \), %          | 26.8                  | 48.4               |
| Release of class more than 0.25mm, % | 1.9              | 1.4               |
| Mass fraction of solid phase \( C_s \), % | 56.9             | 56.6              |
| Effective shear rate viscosity \( \eta \), mPa·s | 178            | 148               |
| Stability, day                     | 15                   | 15                |
| Net calorific value \( Q' \), MJ/kg | 12.22             | 8.24              |

It was experimentally established that the performance of a universal installation for the initial suspension ranged from 0.155 t/h to 0.217 t/h depending on the particle size in the initial suspension. In this operation mode of the installation, the yield of +0.250 mm class in the finished slurry did not exceed the limit required by the combustion conditions \( R_{250} - 5\% \) and amounted to 1.4% - 1.9%.

Combustion of the obtained experimental fuel samples was carried out on a boiler installation consisting of a boiler with a thermal capacity of 0.63 MW, a fuel supply system, an ash collection system, a heat exchanger for heat removal, and draft equipment. The designed and built boiler unit includes a furnace with a vortex combustion chamber, which is located in a water-cooled housing. The WCF is supplied to the vortex furnace through a burner with a pneumomechanical nozzle of the tangentially inner cylindrical surface of the combustion chamber. Also, blast air is supplied tangentially to the combustion chamber. Fuel is sprayed with compressed air. A special feature of the combustion chamber is the presence of a water-cooled clamp, which makes it possible to hold burning coal particles and WCF atomized droplets for the necessary time for their complete burnout [11-13].

The dust collection system is two-stage and consists of a battery cyclone unit and a fabric filter, which provides a high degree of dust removal from the exhaust gases. Table 3 presents the parameters of the combustion process of WCF pilot batches.

Table 3. Parameters of WCF combustion.

| Parameter                          | Mine n.a. S. M. Kirov | “Mine Komsomolets” |
|------------------------------------|-----------------------|--------------------|
| Boiler heating capacity, MW        | 0.47-0.57             | 0.52-0.66          |
| Temperature condition in the chamber, °C | 980 - 1050          | 980 - 1050         |
| WCF consumption, kg/h              | 220 - 250             | 170 - 210          |
| WCF pressure, MPa                  | 0.20                  | 0.19               |
| Compressed air pressure, MPa       | 0.21                  | 0.20               |
Flue gas temperature, °C  250 - 260  250 - 260
Coefficient of performance, %  0.83  0.85

To analyze the chemical composition and completeness of dust and ash burning, samples were taken respectively from flue gases and from the grate located at the bottom of the combustion chamber. All batches of fuel did not differ much in magnitude of underburning – for WCF from fine dispersed waste coal of PP of “Mine n.a. S.M. Kirov” the fuel content in the ash disposal zone (mechanically ignited) amounted to 4.8%, and for fuel of PP of “Mine Komsomolets” – 4.7%, i.e. the magnitude of the mechanical underburning did not exceed 5.0%. During the tests, gas emissions were measured using “Testo 300 XXL” gas analyzer. The sampling process to determine the composition and amount of harmful emissions in the flue gases generated during fuel combustion was carried out at the boiler stable operation.

The composition and amount of harmful emissions from the combustion of prepared fuel samples is given in table 4. As the data in the table show, the obtained values of harmful emissions are significantly less than the permissible values for coal-fired boilers of this capacity when using high-ash fuel.

**Table 4.** Composition and amount of harmful emissions in flue gases.

| Indicator        | MAC *            | WCF from PP of “Mine Komsomolets” | WCF from PP of “Mine n.a. S.M. Kirov” |
|------------------|------------------|-----------------------------------|---------------------------------------|
| Dust, mg/m³      | 250              | up to 170                          | up to 200                             |
| CO, mg/m³        | 375              | up to 75                           | up to 75                              |
| NOₓ, mg/m³       | 750              | up to 250                          | up to 230                             |
| SO₂, mg/m³       | 1200             | up to 200                          | up to 200                             |
| PAH (benzo(a)pyrene), mg/m³ | 0.1·10⁻³ | less than 0.1·10⁻³ |

* - standards for specific emissions of particulate matter, carbon monoxide, nitrogen oxides and sulfur, benzo(a)pyrene into the atmosphere (GOST R50831-95).

Based on the data obtained, a pilot project was developed, which consists of a facilities for the preparation and transportation of fuel-and-chemical fuel and a fuel combustion site.

Facilities for the preparation and transportation of WCF, where fuel was obtained from coal sludges of the above coal processing plants. Design capacity of the workshop is up to 30 t/h. It should be noted that the workshop must be located near the industrial site of the heat power plant or boiler house. The installed capacity of electric motors is approximately 695 kW. The WCF supply to the receiving, feeding and burning site at the heat power plant is carried out through an insulated pipeline with a thermal satellite.
Figure 1. Technological scheme for the preparation of WCF.

Fuel preparation technology. Coal sludge is delivered from the processing plant to the warehouse of the WCF preparation shop by road. The warehouse of coal sludge is located in the workshop. Coal sludge is alternately loaded by the loader into the mixers. The process of WCF preparation consists in mixing coal sludge with an aqueous solution of a plasticizer reagent in the mixer, followed by regrinding of the resulting water-coal suspension in the drum mill. The prepared WCF after homogenization is pumped into storage tanks. The finished WCF is pumped through the pipeline to consumption tanks at the site for receiving, supplying and burning of WCF at the processing plant. Figure 1 shows the technological scheme for the preparation of WCF.

The WCF combustion site. The site must be located in close proximity to the boilers. In the boiler room, two operating boilers are equipped with burner devices (4 pieces for each) with nozzles for supplying and spraying WCF with compressed air. The possibility of WCF spraying with steam of the corresponding parameters is also provided. During the operation of the complex, the WCF consumption for each boiler is 15 t/h with the corresponding coal replacement (up to 30%). The annual operating time fund of the boiler is 6,800 hours, the installed capacity of electric motors is 563 kW.

The scheme of the proposed pilot complex is presented in figure 2.

Figure 2. Scheme of the pilot technological complex.

Technological solutions. It is planned to install 2 consumption tanks for WCF V=200 m³. Vertical cylindrical tanks for storing liquid products with heating and thermal insulation. In the pumping station,
pumps for supply WCF to nozzles are installed, equipped with adjustable drives, which allows the required fuel consumption to be set and maintain. The compressor station serves to supply compressed air to the nozzles for spraying fuel. In order to maintain the boiler’s steam capacity when supplying WCF to the boilers, a corresponding (in calorific value) reduction in the natural gas supply is carried out. Partial replacement of natural gas by WCF does not require additional personnel for maintenance, replacement or modernization of draft equipment, ash and slag removal systems, gas treatment, and the introduction of special reconstruction elements. This ensures the stable operation of the boiler in nominal mode.

4. Conclusion
In the course of the work, technology and equipment were developed for the preparation and burning of WCF, obtained on the basis of fine dispersed coal waste (filter cakes) from the processing plants of “Mine Komsomolets” and “Mine n.a. S.M. Kirov”. It is shown that on the basis of these wastes it is possible to prepare WCF with a solids content 56-60%, with the required structural and rheological characteristics and lower heat value up to 13 MJ/kg.

The working design of the pilot technological complex for the preparation and combustion of WCF was developed, which ensures high efficiency of the boilers (efficiency is 83-86%) with the significantly lower level of harmful emissions in flue gases than permissible values.

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