The development of ecologically clean technology for coal use in terms of the coal-water slurry usage

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Abstract. The baseline conditions of technology for producing and burning coal-water slurries in Russia and foreign countries is exposed. The technological and economic efficiency of using this technology for the coal processing and cleaning waste disposal is shown at experimental and industrial facilities. The feasibility studies of the technology usage at large Kuzbass thermal power plants are presented. The possibility of solving a serious environmental problem of reducing the storage of the most coal washing toxic waste volume in the areas where coal processing plants and coal mining enterprises are located is demonstrated. It is shown that on the basis of these wastes, it is possible to prepare a suspension coal-water fuel with a solid phase content of 56-59%, with the required structural and rheological characteristics and a lower calorific value of up to 13 MJ/kg. The boiler with a thermal capacity of 0.58 MW with an eddy combustion system, which effectively operates on coal-processing waste fuel is designed, manufactured and tested. The results of the boiler operation on the specified fuel showed its high efficiency (efficiency is 83-85%) with the level of harmful emissions in the flue gases significantly lower than the permissible values.

1. Introduction
A significant environmental problem for the Russian coal regions is the existence of in the form of settling tanks, hydraulic dumps, or sludge pads. It should be noted large fine-grained coal sludge volumes generated during the coal mines and washing plants operation. In fact, there are large areas near each mine or washing plant that are occupied by these slurries that these products contain most of all the chemical reagents that were used in the coal enrichment process (floculants, coagulants, etc.). In addition to direct environmental damage (surface soil pollution, water runoff, dust storms, etc.), the operation of such facilities requires significant economic costs. In many world countries of the (USA, France, China, etc.), this problem is solved by using these coal slurries as the main or additional fuel for nearby coal-fired power plants [1-8].

The coal-water slurry production technology is one of the most effective technologies for producing environmentally friendly and technologically advanced fuel. This technology is successfully used in the energy sector of a number of foreign countries, although the main developments were carried out in Russia in the middle of the last century. At this moment China's energy sector is successfully using this experience. [1].

There is also a long and successful experience of operating the Emile Guchet power plant in France [2], which implemented a project for direct combustion of coal sludge in the form of suspension in boilers with a circulating boiling bed. Complete coal sludge utilization using this technology was
carried out at several thermal power plants in the United States. The technology of preparation and combustion of coal-water fuel obtained on the basis of both coal and sludge is widely used in China.

In this case, the combustion of coal slurries, which are usually substantially water- and ash-blasted fuel, is usually carried out in boilers with a boiling bed in the form of a water-coal suspension or coal paste. The specified energy use of energy slurries or fine coal-processing waste (TDE) is economically feasible only if they are located near the combined heat and power plant (within a radius of no more than 40-50 km). These conditions may not always be met. In this case, the effective use of TDE as the basis for fuel requires the construction of a mini-thermal power plant, which is associated with significant capital costs and organizational problems.

The work purpose is to show the possibilities of widespread implementation of environmentally friendly technology for preparing and burning coal and coal sludge in the form of coal–water slurries while solving the problems of resources efficient use and improving the environmental situation in coal-mining regions.

2. Results and discussion
The eddy combustion system with a boiler of adiabatic or similar to it conditions developed and successfully used for reliable burning the significantly sealed with moisture and mineral components coal-water slurry fuel prepared on the basis of fine waste and other coal products.

The use of eddy combustion technology made it possible to successfully complete several projects with the reconstruction of small and medium power boilers [5].

Currently, the effective plasticizing reagents formulations have been developed, which allowed us to obtain a statically and dynamically stable water-coal fuel with the thermophysical characteristics required for direct combustion. In order to stabilize the technological characteristics of the coal-water slurry fuel prepared on the basis of waste fine coal, the technological scheme (figure), in which the role of the finished fuel ash content "stabilizer" carries out the coal-preparation plant industrial product (OF), is developed.

The coal-water slurry fuel experimental batches based on fine coal-processing waste were prepared at the test bench coal fuel preparation site. Figure 1 shows the technological scheme of coal-water slurry fuel preparation. According to the technological scheme the initial filter cake and a plasticizer reagent aqueous solution were fed to a batch mixer, then, the resulting coal-water slurry was dosed to a universal vibration unit, where the resulting fuel was ground and additionally mixed. The universal vibration unit is a bi-chamber vibrating mill which consists of concentrically arranged cylindrical chambers loaded with balls and connected by channels. The initial slurry enters the inner chamber of the vibrating mill, moves down and through the channels enters the outer chamber. In the outer chamber, the slurry moves upwards. The crushed material is discharged through the outer threshold of the outer chamber. This vibrating mill operation principle allows you to ensure the low energy consumption for grinding particles in the mixture with the required size of large particles in the finished fuel. The prepared coal-water slurry fuel was pumped into storage tanks.

This technology (figure 1) can be successfully implemented at coking coal processing plants that have certain difficulties with the sale of industrial products. The fact is that its traditional methods combustion (on a grate, in a fluidized bed, etc.) is ineffective. The construction organization of mini-thermal power plants with obtaining cheap own electricity and heat based on the industrial products and filter cake combustion using the coal-water slurry fuel technology is economically justified.

It was found experimentally that the universal unit capacity for the initial slurry varies in the range of 0.155 t/h - 0.217 t/h, depending on the particle size in the initial slurry. In this unit operation mode the output of the +0.250 mm class in the finished slurry did not exceed the limit required by the combustion conditions (R250≤5%) and was 1.4% - 1.9%.

2
Figure 1. Basic technological scheme for the preparation of slurry coal fuel based on products at a bench installation

Figure 2. Basic technological scheme for the preparation of slurry coal fuel based on coal processing products

The coal-water slurry fuel experimental batches were burned at a boiler plant consisting of a boiler with a thermal capacity of 0.58 MW, a fuel supply system, an ash collection system, a heater for heat removal, and draft equipment. The created boiler consists of a furnace – an eddy combustion chamber
located in a water-cooled housing and an economizer for removing heat from hot flue gases formed in the furnace. The ballasted fuels combustion processes in such combustion systems are poorly studied at the moment. The coal-water slurry fuel supply to the eddy furnace is carried out through a burner device with a pneumatic mechanical nozzle tangentially to the combustion chamber inner cylindrical surface. Blast air is also supplied tangentially to the combustion chamber. Fuel is sprayed with compressed air supplied to the nozzle. The fuel supply is regulated by changing the fuel pump engine speed. The furnace combustion chamber is equipped with a water-cooled clamp, which allows you to keep burning coal particles and the coal-water slurry fuel sprayed drops in the necessary time for their complete burnout.

The dust collection system is two-stage and consists of a block of battery cyclones and a fabric filter, which provides a high degree of outgoing gases cleaning from dust. Figure 3 shows the effect of the resulting slurry fuel ash content on the amount of the fuel supplied at a boiler capacity of 0.58 MW and different solid phase content.

![Figure 3](image_url)

**Figure 3.** Fuel ash content influence on its consumption: - solid phase content 57%; - solid phase content 59%

The data in the figure show that an increase in ash content leads to a corresponding increase in the amount of fuel supplied for combustion while maintaining the boiler's heating capacity.

In order to analyze the chemical composition, as well as the burnout completeness, dust and ash and slag waste (ash) the coal-water slurry fuel were compared in the process of raw materials obtained from two different processing plants. During the tests gas emissions were measured using the "Testo 300 XXL" gas analyzer. The sampling process for determining the composition and amount of harmful emissions in the flue gases generated during fuel combustion was carried out with a stable working boiler.

The plasticizing additive composition and influence on the rheological characteristics of the resulting fuel is determined; the fuel consumption dependence on its ash content is established.

Measurements were made accordingly from the flue gases and from the grate located at the bottom of the combustion chambers. All fuel batches differed little in the underburning amount - for sample №1, the coal-water slurry fuel from fuels in the ash (mechadoll) was 4.8%, and for fuel made from sample № 2 – 4.7%, i.e. the mechadoll value did not exceed 5.0%. Almost complete burning of the coal organic mass reduces emissions of harmful substances into the atmosphere and produces ash with good characteristics for its use in the construction industry.

3. Conclusion

The technology and equipment for the preparation of slurry water-coal fuel obtained from fine-dispersed coal enrichment waste of processing plants (filter cakes) have been. It is established that on the basis of these wastes, it is possible to prepare a slurry coal-water fuel with a solid phase content of 56-60%, with the required structural and rheological characteristics and a lower calorific value of up to 13 MJ/kg.
The boiler with a thermal capacity of 0.58 MW with an eddy combustion system, which effectively operates on fuel from waste coal for small and medium-power boiler plant, is developed, manufactured and tested. The boiler operation results on the specified fuel showed its high efficiency (efficiency is 83–85%) with the level of harmful emissions in flue gases significantly lower than the permissible values. High indicators were achieved for the level of mechanical and chemical fuel combustion (respectively, no more than 5% and 80mg/m3, which is much less than the permissible values). Thus, it is shown that it is possible to reduce harmful emissions when burning coal-water fuel from coal enrichment waste.

In many world countries the technology of slurry coal-water fuel preparation and combustion in boilers of various capacities has been developed. It is shown that the greatest economic feasibility and significant environmental effect are achieved when using coal-water fuel obtained from coal slurries in experimental and industrial conditions. In this case, an important problem is solved for the disposal of the most coal enrichment toxic fine waste, the storage of which requires significant areas in the coal mining and processing regions.

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