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The creation of a low-capacity boiler plant on coal-enrichment waste

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***Abstract*—A serious problem for coal production is the environmentally friendly utilization of coal mining waste and coal enrichment. In different countries, the best specialists in this field are trying to find the solution of this problem. In the United States, France and China, the technology of preparation and burning of water-coal suspensions (WCS) for the utilization of fine-dispersed wastes of coal enrichment and coal slurries has been successfully used. A boiler with a thermal capacity of 0.63 MW with a vortex combustion system efficiently operating on fuel from coal waste was designed, manufactured and tested. The results of the operation of the boiler on this fuel showed its high efficiency (the efficiency is 83-86%) with the level of harmful emissions in the flue gases below the permissible values**

Keywords—ash-and-slag wastes, fine waste of coal enrichment, a boiler with a vortex combustion system

I. INTRODUCTION

A serious problem for coal production is the utilization of coal mining waste and coal enrichment. At present, around each large mine, surface mine or coal-processing plant, "tails" are formed - huge stores of wet or liquid waste. Such coal waste is called coal slurry. The medium-sized coal-processing plant produces from 300 to 600 tons of slurry daily - the same "tails" that are stored in numerous sludge pits or rock dumps [1-3]. The use of carbonaceous wastes is economically advantageous for many enterprises and, especially in coal mining areas, but under the condition of efficient combustion. Coal-containing waste in coal mining regions has a negative cost (storage and landfill maintenance costs) [4]. At present, practically all-Russian coal-preparation plants have their own boiler plants for heat supply and hot water supply. Boilers installed in boiler plants are usually equipped with combustion furnaces with layer combustion of coal. The efficiency of these boilers is from 50 to 70%, which is due to high mechanical and chemical underburn. In addition, boilers with layered furnaces are not designed to burn enrichment products such as industrial products, coking coals and fine coal slurries, for example, filter cake [5-10].

The most effective, in this case, way of burning high-ash waste of coal enrichment is burning in the form of water-coal fuel suspensions. In the USA, France and China, the technology of preparation and burning of water-coal suspensions (WCS) for the use of fine-dispersed waste coal and coal slurries in power engineering is successfully used. This fuel has its own characteristics, which must be taken into account when creating a heat generator working on such fuel. For economical, environmentally cleaner burning of coal and involvement of low-grade ballasted fuels and waste in the fuel balance of enterprises, it is necessary to develop scientific foundations for organizing highly efficient combustion technologies and accumulating practical experience in their operation. The aim of the work was to create a heat generator of small and medium power, which could work on high-ash waste of coal-enrichment.

II. RAW MATERIALS AND METHODS OF WCS PREPARATION

For the preparation of suspension water-coal fuel, representative samples of fine-dispersed waste of coal enrichment (FDWCE) - filter cakes from the filtration departments of the CPP the mine “Komsomolets” (Leninsk-Kuznetsky city, Kemerovo region) were used. The characteristic of the FDWCE is presented in Table 1.

TABLE I. QUALITATIVE CHARACTERISTIC OF THE FILTER CAKE

Indicator name	**Numeric value**
Moisture, general, W_t^r, %	34,8
Ash content (dry condition of fuel), A^d, %	26,8
The yield of volatile substances (on the dry ashless state of the fuel), V^{daf}, %	43,1
Sulfur common (dry fuel), S_t^d, %	0,48
The highest heat of combustion (on a dry condition of fuel), Q_s^{daf}, MJ/kg	33,04

The lowest heat of combustion of the working fuel, Q_t^r, MJ	14,3
Granulometric composition, mm,%	
0,250 – 3,0	8,4
0,071 – 0,250	18,7
- 0,071	72,9
Total	100,0

Evaluation of the preparation possibility of water-coal fuel from coal-washing wastes and selection of the optimal plasticizing additive were carried out under laboratory conditions on a universal shaker stand.

During the studies, samples of suspension coal fuel in an IED grinding chamber were prepared from a mixture of filter cake and an aqueous solution of the plasticizer reagent. The amount of water and the content of the plasticizer in it were determined by calculation, depending on the quality of the starting product. The obtained samples of WCS were analyzed for the mass fraction of the solid phase, the particle size distribution, viscosity and stability. The mass fraction of the solid phase was determined by the standard drying method in accordance with GOST 27314-91, the granulometric composition by wet sieving in accordance with GOST 2093-82. The lowest heat of combustion was determined by calculation in accordance with GOST 27313-87.

On the basis of the laboratory tests, the most effective plasticizer was determined, the consumption of which was 0.25% of the solid phase in the fuel.

III. Preparation of WCS pilot lots based on the FDWCE

Experimental lots of WCS based on the FDWCE were prepared at the coal preparation section of the experimental stand. Figure 1 shows the technological scheme for the WCS preparation.

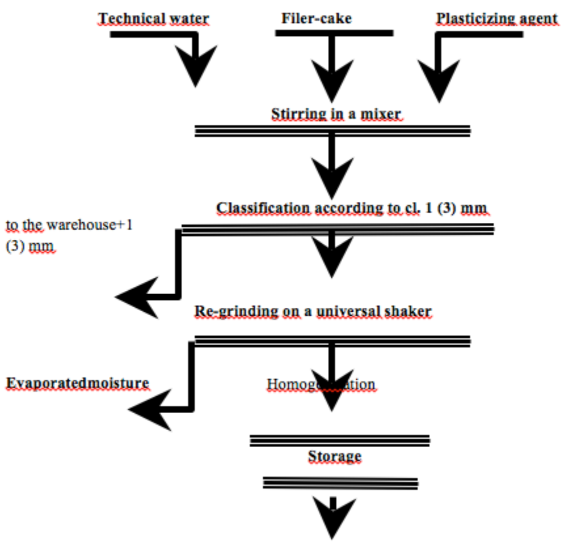


Fig. 1. Flow chart of WCS preparation from the filter cake

According to the flow chart, the initial filter cake and the aqueous solution of the plasticizer reagent were fed into a batch mixer, then the resulting water-coal suspension was dosed to a universal shaker, where there was further grinding and further mixing of the obtained fuel. The prepared WCS was pumped into storage tanks. Table 2 shows the structural-rheological and thermophysical parameters of the WCS.

TABLE II. Characteristics of the prepared pilot lots of WCS

Ash A^d, %	**Class output is more 0,25mm, %**	**Mass fraction of solid phase, $C_т$, %**	**Effective viscosity at shear rate 81 s^{-1}, η, mPa·s**	**Stability, day**	**Net calorific value, Q_i^r, MJ/kg**
26,8	1,9	56,9	178	15	12,22

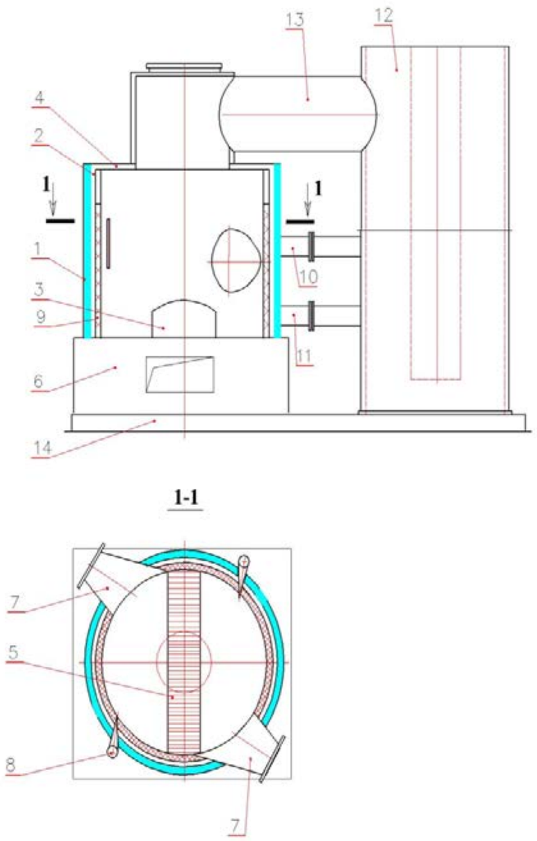
It was experimentally established that the productivity of a universal plant for the initial suspension varies in the range 0.155 t / h - 0.217 t / h, depending on the particle size in the initial suspension. In this mode of operation, the output of the class + 0.250 mm in the finished suspension did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

IV. WCS burning at the experimental stand

The boiler (see Figure 2) consists of a vertical cylindrical body 1 with a water-cooled jacket 2, a door 3 and a lid 4, a grate 5 and an ash pan 6. The outer surface of the cylindrical body is thermally insulated. Burner devices 7 with nozzles (not shown in the figure) and slit nozzles 8 for tangential supply of blast air are mounted on the side surface of the casing. The inner cylindrical surface of the combustion chamber above the grate is thermally insulated with heat-resistant material 9. For connecting and discharging the heat-transfer fluid, the pipes 10 and 11, respectively, are installed. For heat removal, a heat exchange system 12 is provided between the hot combustion products and the heat carrier. The boiler body and the heat exchange system are connected by the flue 13. The boiler body with the ash pan and the heat exchange system are mounted on the frame 14.

Initially, the internal cavity of the boiler body is heated - the combustion chamber placed above the grate, by burning solid fuel on the grate. Subsequently, the supply of a suspension water-coal fuel begins [11, 12].

a.)



b.

Fig. 2. Construction of the boiler.

Suspended coal-water fuel is supplied to the boiler by a pump from the storage tank through the nozzles of the burner devices 7. The spraying compressor air is also supplied to the nozzles. Sprays of atomized fuel are supplied tangentially to the conventional surface inside the combustion chamber of the boiler body 1. At the same time, tangentially into the combustion chamber air is supplied through the slotted nozzles 8 oriented in the same direction as the burners. Due to the organization of vortex motion in the boiler body, effective combustion of the atomized fuel is carried out [13]. Possible unburned coarse coal particles fall on the grate 5, where they burn out, creating an additional "lighting" in the combustion zone of the atomized fuel. Large particles of ash and slag deposits accumulated on the grate are periodically unloaded into the ash pan 6. The hot gases generated by the combustion of the fuel through the internal cavity of the boiler lid 4 and the flue 13 enter the heat exchange system 12. As a result, heat exchange takes place between the hot gases and the heat transfer fluid. Partial heat exchange between the combustion products and the heat transfer fluid also occurs in the boiler body due to the presence of a water-cooled jacket 2. Reliable and efficient operation of the boiler is also ensured by the presence of adiabatic or close to them conditions in the combustion zone of the fuel [14].

Transportation of flue gases from the furnace to the economizer is provided by a smoke exhaust fan. After the economizer, the flue gases enter a two-stage dust collector, and then they are thrown into the atmosphere through a chimney [15].

Figure 3 shows the WCS from the filter cake, the appearance of the heat generator and the burning process of the fuel.

Fig. 3. WCS from the filter cake and the burning process of the fuel.

TABLE III. TEST RESULTS

The name of indicators	Under the project	Actually achieved
Heating capacity of the boiler, MW	0,63	0,65
The lowest heat of combustion of fuel, kcal / kg	3000-3100	2600÷3400
Fuel consumption, l / h	300	160÷370
Temperature in the furnace, °C	1050±50	1100±100
Flue gas temperature , °C	180	180
Water temperature , °C: - at the entrance - at the exit	60 80	55 87
Efficiency of boiler , %	0,85	0,86

During testing of the experimental setup, the fuel consumption, taking into account the change in the net calorific value of WCS, varied from 205 kg / h to 370 kg / h. The temperature in the furnace was 1000 - 1100^{0}C.

The composition and amount of harmful emissions from combustion of fuel samples prepared on the basis of fine coal waste from the coal mine “Komsomolets” showed that the obtained values of harmful emissions are significantly lower than the allowable values for coal boilers of this power when using high-ash fuel (dust, mg / m^3 - not more than 170, CO, mg / m^3 - not more than 75; NOx, mg / m^3 - not more than 250; SO_2, mg / m^3 - no more than 200, at specifications:

dust - 250 mg / m^3, CO - 375 mg / m^3, NOx - 750 mg / m_3, SO_2 - 1200 mg / m^3).

CONCLUSIONS

(1) As a result of the work performed, a boiler with a thermal capacity of 0.63 MW with a vortex combustion system efficiently operating on fuel from coal waste was developed, manufactured and tested. The results of the boiler operation on this fuel showed its high efficiency (the efficiency is 83-86%) with the level of harmful emissions in the flue gas significantly below the permissible values.

(2) The technology and equipment for the preparation and combustion of small and medium-power slurry water-coal fuel, obtained from fine-dispersed coal cleaning waste (filter cakes) from the mine “Komsomolets” coal-preparation plant were developed. It is shown that on the basis of these wastes it is possible to prepare a suspension water-coal fuel with a solid phase content of 56-60%, with the required structural-rheological characteristics and a net calorific value of up to 13 MJ / kg.

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