Increasing the calorific value of Angren lignite coal by an upgraded device

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Abstract: the article presents the classification of the improved drying and enrichment device for increasing the calorific value of Angren B2 coal, the behavior of heat carriers, physical model, operation process, hydrodynamics of the abstract fluidized bed. Experiments were carried out on this device, preliminary results were obtained, and examples of analyzes that determine the reliability of the research are presented. The empirical equation of the results of the research is defined in term 6 in the polynomial linear equation and shown using a graph. In addition, the reliability of the research results was analyzed by regression and the reliability was 96%.

1. Introduction

Uzbekistan is one of the leading countries in the world in terms of wealth of large coal reserves. Angren coal mine is one of the largest mines in Central Asia. 85% of the solid fuel produced in our country is accounted for by this mine. A system of regular delivery of mined coal to the population and budgetary organizations has been established. Analyzes show that the demand for coal products in our country is growing. In the period from 2010 to 2016, the population and budget organizations' need for coal increased by 2.5 times. Based on this demand, investment projects aimed at increasing the volume of coal mining and delivery to consumers are being implemented in industry enterprises. As a result of such measures, the volume of coal production increased from 3.3 million tons to 4 million tons, and the amount of solid fuel supplied to consumers increased from 2.5 million tons to 3.7 million tons. Most of the lignite mined from the Angren mine is mainly used as fuel by the Angren Thermal Power Plant (TPP). The efficiency of the station depends on the quality of the coal. Therefore, the main task of the research work is to increase the calorific value of Angren lignite by drying and enriching it and to supply high-quality coal to the station. A new improved coal drying and beneficiation device was proposed to fulfill these tasks. The composition of coal currently used in thermal power plants is presented in the Table.1 below.

Table 1. The chemical composition of Angren lignite coal presented [13].

Lignite coal brand	Average chemical composition							
	C, %	O_2, %	H_2, %	N, %	S, %	Volatile substances,%	Moisture,%	Ash,%
Б2	55-95	5-15	1.5-5.7	0-1.5	0.5-4	45-2	14-28	20-45

As can be seen from the table, coal has a high ash and moisture content, which leads to a decrease in the caloric value of the fuel. The coal preparation process used in the Angren thermal power station (TPS) is very complex, which is disproportionate to the economics of the station. In addition, because Angren B2 lignite coal has a high ash and moisture content, additional energy is required for drying and enrichment. Therefore, it is intended to use the hot flue gases released during fuel combustion at the Angren TPS as secondary energy, and carry out coal enrichment and drying operations in one installation [2]. Below we will look at a new technology to solve the problem.

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2. Materials and Methods

To solve the problem, an experimental copy of the abstract fluidized bed drying and enrichment device was created.

The following are used as a drying medium for an abstract fluidized bed drying device: heated air, flue gases or mixtures of flue gas with air. Below is a lignite coal drying and enrichment process through fluidized bed devices.

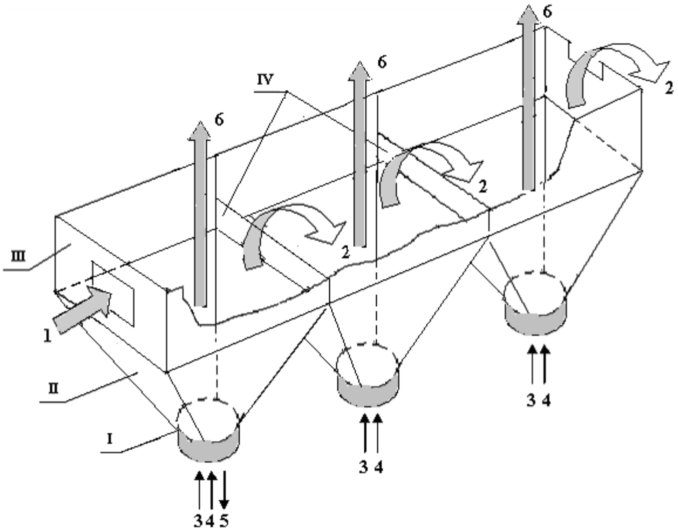
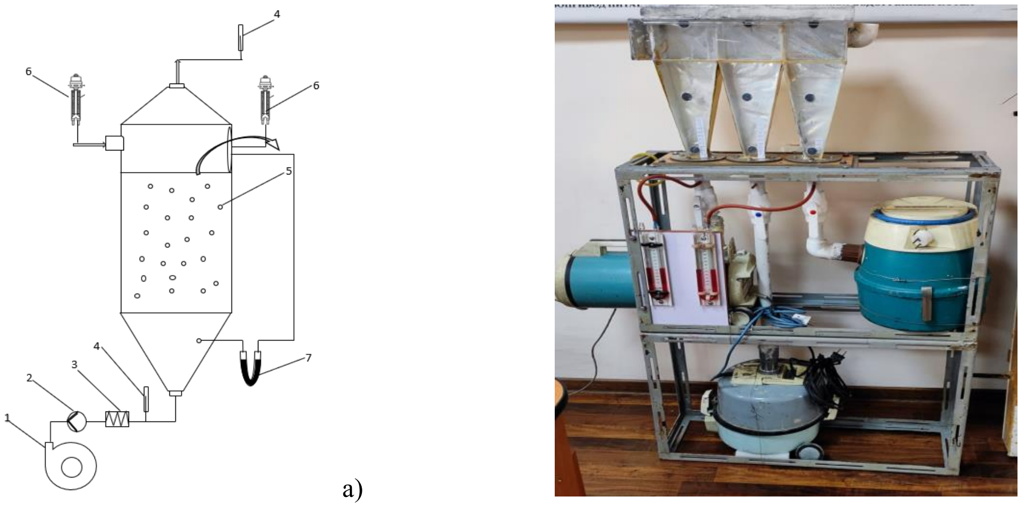


Fig. 1. Drying and enriching the coal with the fluidized bed device [9]
1- fuel supply pipe, 2- working chamber, 3, 4- air (flue gas) supply corridor, 5- path for removal of wet and hard mineral residues, 6- air movement direction

In this case, the coal size should be in the range of 2 mm - 20 mm. The proposed device consists of a working chamber in the form of a parallelepiped, a cone shaped air passage and a fuel inlet pipe, and several such devices are attached. Coal is supplied to the chamber through the fuel supply pipe, and hot air is supplied from the lower part, that is, through the conical passage. Due to the good insulation, the device retains heat well and the drying process is improved [16]. As the air is supplied at high speed, the coal pieces rise to a certain height. Wet and dry coal pieces are separated according to the weight of coal moisture content. With this speed, the dry coal pieces fly to the next chamber, while the wet coal pieces and hard minerals cannot pass due to their high weight and are separated through the tube. Through this, in both chambers, clean coal separated from unnecessary substances and coal pieces with solid substances and moisture are separated [3-6; 11; 12]. A technological scheme and a research model were created to conduct experiment on this device.



a) b)

Fig. 2. a)-technological scheme. 1-Air drive pump, 2-Rashodomer, 3-Colorifer, 4-Thermometer, 5-Experiment device, 6-Psychrometer, 7- U-shaped manometer. b) actual view of the experimental device.

The main task of the device is to organize the process of fluidized bed, thereby drying coal and separating it from solid minerals. Based on the theoretical data, an experiment was conducted in the research device. Angren B2 lignite coal of different weight was fed into the chamber, the speed of the supplied air was determined in the anemometer, and the hydraulic resistance was measured in the manometer.

This requires the study of fluidized bed process equations. When the velocity of the supplied air overcomes the hydraulic resistance, the abstract fluidized bed begins. The process of abstract fluidizing is when the particles of coal are suspended in the air and appear as if they are boiling. The speed at this time is the first critical speed, and the speed at which the coal pieces fly to the next chamber is the second critical speed. So, it follows that we can see the essence of the process mainly by determining the air velocities and hydraulic resistance.

The hydraulic resistance of the fluidized bed ΔP is equal to the ratio of the cross-sectional area S of the device and the weight G of solid particles [7].

$$\Delta P = \frac{G_k}{S} \tag{1}$$

Below is the weight of solid particles,

$$G_k = F \cdot H \cdot (1 - \varepsilon) \cdot \left(\rho_{q.z} - \rho_m\right) \cdot g \tag{2}$$

here H is the height of the layer, m; ε - void volume in the layer; $\rho_{q.z}, \rho_m$- density of solid particles and the environment kg/m^3.

As the velocity w increases, the layer height H and void volume ε increase. But as (1 - ε) decreases, H*(1 – ε) does not change, because the hydraulic resistance of the abstract fluidized bed does not depend on the value of the fictitious velocity w_0. The relationship between the heights of the constant layer and the abstract fluidized bed can be found from the following expression:

$$H \cdot (1 - \varepsilon_0) = H_0 \cdot (1 - \varepsilon) \tag{3}$$

H_0- constant layer height, m;

The void volume of the abstract fluidized bed is found from this equation:

$$1 - \frac{H_0 \cdot (1 - \varepsilon)}{H} = \varepsilon_0 \tag{4}$$

here H_0/H is the coefficient of expansion of the layer. It shows how many times the volume of the abstract fluidized bed is larger than the volume of the constant layer. For a spherical unit particle, when $\varepsilon = 0.4$, the first critical velocity is found using the equation of prof. O.M. Todes [11]:

$$Re_{kr1} = \frac{Ar}{1400 + 5.22\sqrt{Ar}} \tag{5}$$

Here:

$$Re_{kr1} = \frac{w_1 \cdot d\rho}{\mu} = \frac{w_1 \cdot d}{\vartheta} \tag{6}$$

$$w_1 = \frac{Re_{kr1} \cdot \mu}{d\rho} \tag{7}$$

$$Ar = \frac{d^3 \cdot (\rho_{q.z} - \rho_m) \cdot g}{\mu^2} \tag{8}$$

The speed of exit of solid particles with gas or liquid flow or the second critical speed is found by the equation of prof. O.M. Todes:

$$Re_{kr2} = \frac{Ar}{18 + 0.575\sqrt{Ar}} \tag{9}$$

$$Re_{kr2} = \frac{w_2 \cdot d\rho}{\mu} = \frac{w_2 \cdot d}{\vartheta} \tag{10}$$

$$w_2 = \frac{Re_{kr2} \cdot \mu}{d\rho} \tag{11}$$

here A_r is Archimedes' criterion; θ- kinematic viscosity, m^2/s; d - solid particle diameter, m [15].

3. Results and Discussion

In the graph, we can see that as the speed of the air supplied to the device increases, so does the pressure. Upon reaching a certain critical point, that is, when air is supplied at a speed that can overcome the gravity of the coal, the pressure suddenly drops. Because the pieces of coal go into a weightless (abstract) state, the resistance quickly drops to a certain amount and does not change. The velocity at the start of this process is the first critical velocity and can be theoretically determined using equation (7). The first critical speed is determined depending on Reynolds' criterion (5), Archimedes' criterion (8), including the density of coal equivalent diameter. As a result of the high speed that can support the weight of the coal pieces, the particles begin to fly into the next chamber. The speed at which this process begins is called the second critical speed and is determined using Equation 11. The second critical speed is also determined depending on the speed Reynolds' criterion (10), Archimedes criterion (9). Between the first and second critical speeds, the pressure remains constant, and this is clearly visible in the graph. At a speed higher than the second critical speed, some of the particles move to the next chamber, and the weight of the particles in the first chamber decreases, correspondingly, the pressure also decreases.

The obtained results were entered into the excel program and graphs were made based on the results and the empirical equation of the graph was established using the polynomial module. And the results were obtained and graphed by feeding several coal pieces up to m = 200 g into the chamber.

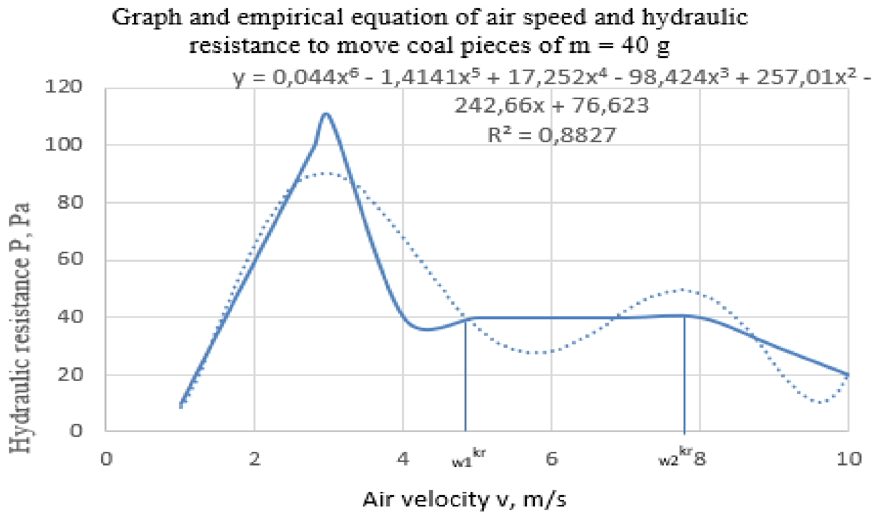


Fig. 3. Graph of dependence of air speed and resistance in the fluidized bed coal pieces of different weights [12]

A regression analysis was performed to check the accuracy of the obtained results [17]

Table 2. Comparing experimental results with regression analysis

Regression statistics	
Several R	0,984590697
R-squared	0,969418841
normalized R-squared	0,964321981
standard error	1,185878825
Number of observations	43
Common error	6.79%

The reliability of the experimental results in the regression analysis was 96%, the value of other types of analysis is given in the table below, and the graph shows the comparison of the experimental results and the results of the regression analysis.

In the graph below, the airspeed variation is analyzed and 43 results are obtained and this is represented by the blue line, and their level of accuracy is shown by the red line. It can be seen that the precision line of the experiment does not deviate much from the straight line, thus confirming the reliability of the device.

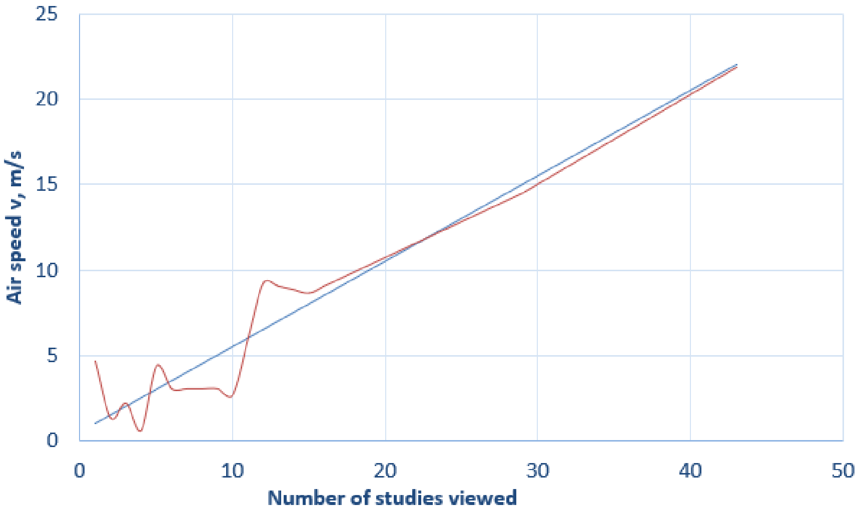


Fig. 4. The result of the experiment is the closeness of the regression analysis results

Calculation of the calorific value of coal during operation of the unit is given below, and the coal ash content is 40%, moisture content is 28% and the lower heat of combustion is 2200 kcal/kg
Initially, with the help of the device, the moisture content was reduced to 10%, thereby increasing the lower combustion heat by 1.45 times. [8; 14].

$$Q^P_{H2} = (Q^P_{H1} + 25.1 * W^P_{H1})\left(\frac{100 - W^P_{H2}}{100 - W^P_{H1}}\right) - 25.1 * W^P_{H2}$$

$$= (2200 + 25.1 * 40)\left(\frac{100 - 10}{100 - 28}\right) - 25.1 * 10 = 3204 \text{ kkal/kg} \qquad (11)$$

By reducing the amount of ash from 40% to 20%, the caloric value increased by 1.33 times.

$$Q^P_{H2} = Q^P_{H1} * \left(\frac{100 - A^P_{H2}}{100 - A^P_{H1}}\right) = 2200 * \left(\frac{100 - 20}{100 - 40}\right) = 2933 \text{ kkal/kg} \qquad (12)$$

If it is possible to reduce both quantities, that is, ash and moisture at the same time, then the device will be able to increase the heat of lower combustion up to 3 times.

$$Q^P_{H2} = (Q^P_{H1} + 25.1 * W^P_{H1})\left(\frac{100 - W^P_{H2} - A^P_{H2}}{100 - W^P_{H1} - A^P_{H1}}\right) - 25.1 * W^P_{H2}$$

$$= (2200 + 25.1 * 40) * \left(100 - 10 - \frac{20}{100} - 28 - 40\right) - 25.1 * 10$$

$$= 6757 \text{ kkal/kg} \qquad (13)$$

4. Conclusions

In conclusion, it can be said that
1. The results of theoretical calculations showed that the newly proposed device will increase the heat value of coal by 3 times, and it was given in equation (13).
2. The result of the study shows that the device is simple and reliable (96%).
3. There is an opportunity to increase the efficiency of the thermal power plant by putting the device into practice.

4. This device leads to a decrease in the energy demand of the layer that uses low-power coal fuel in the economic network, and to a decrease in harmful gases released into the atmosphere as a result of the combustion of high-quality fuel.

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