The influence of wood processing waste on the technical and energy characteristics of the Maikuben coal-based mixed fuels

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Abstract. The manuscript presents the results of experimental studies of the energy and technical characteristics of mixed fuels based on lignite from the Maikuben basin of the Republic of Kazakhstan and wood processing waste, pine sawdust from the Tomsk LPC. The addition of wood biomass to coal is found to result in a significant reduction in the ash content of the mixed fuel (by 73.1 %) with a wood fraction equal to 50 % and a moderate reduction in calorific value (by 8.2 %) with the same concentration of biomass in the mixed fuel.

1. Introduction
Reducing the impact of power companies on the environment is one of the most important tasks of the entire world community [1]. The main fuel of many power plants is coal [2, 3], which produces greenhouse gases such as nitrogen oxides, sulfur oxides, and fly ash [4, 5]. The search for alternative sources of heat and electricity production in recent decades has shown (for example, January 2021 [6]) that traditional solid fossil fuels will remain one of the main energy carriers for more than a decade [7]. Despite the improvement of solid fuel combustion processes and the modernization of flue gas treatment systems [8], the level of reduction of anthropogenic gas emissions by coal-fired power plants worldwide is insufficient to improve the ecology of the planet [9, 10]. One of the alternative ways to reduce the anthropogenic impact of coal-fired thermal power plants on the environment is the use of biomass (carbon-neutral component) in a mixture with coal [11, 12]. But the mechanism of its influence on the processes of reducing emissions of anthropogenic combustion products when burnt with coals of various grades is still not justified.

The aim of this work is to experimentally determine the effect of wood waste, as an additive to coal from the Maikuben deposit in Kazakhstan, on the technical and energy characteristics of the mixture, in comparison with homogeneous coal.

2. Experimental section
Lignite from the Maikuben basin in Kazakhstan was used as the initial component. Previously, an analytical sample was selected, and grinding was performed in a ball mill. The milled coal was sifted through sieves of 80 microns.

The biomass used was wood from one shift of Tomsk LPC, LLC production company (Russia, Tomsk). The sawdust was previously cleaned from large wood inclusions (wood chips, bark), then sifted through sieves of 200 microns. An analytical sample was formed after sifting. Further, mixed fuel samples were prepared on the basis of the two initial components in the range of biomass concentrations to coal from 10% to 50% by weight.
The technical characteristics of the studied mixed fuels (calorific value, ash content, moisture content, and volatile yield) were determined in accordance with the methods described in GOST 147-2013 (ISO 1928-2009), GOST 11022-95, GOST 27314-91 (ISO 589-81), GOST 6382-2001.

In order to determine the ignition delay times of the studied mixed fuels, the setup [13] was used. Figure 1 shows a schematic diagram of the experimental setup.

Figure 1. Schematic diagram of the setup for determining ignition delay times of floating particles of mixed fuels. 1 – temperature-controlled combustion chamber; 2 – floating particles located in the combustion chamber; 3 – dispenser of fuel particles; 4 – high-speed video camera; 5 – connection line between monoblock and high-speed video camera; 6 – connection line between thermocouples and signal converter; 7 – thermocouples signal converter; 8 – connection line between thermocouples signal converter and monoblock; 9 – monoblock [13].

Experimental studies of the ignition processes of mixed fuels based on fine lignite from the Maikuben deposit (Kazakhstan) and crushed sawmill waste (pine sawdust) were carried out in several stages. The required air temperature (from 500°C to 800°C) was set in a vertically arranged cylindrical chamber. The temperature field in the temperature-controlled chamber was controlled by two thermocouples with the following characteristics: platinorodium-platinum thermoelectric converters, operating temperature range of 0–1350°C, and error of no more than ±1%. All experimental studies were performed in an oxidation environment (air) [13]. The combustion chamber was not blown because the velocity of coal and wood particles slightly differs from the gas flow velocity at the points corresponding to the position of fuel particles in a real furnace environment [13]. The smaller the characteristic particle size (and, consequently, their mass), the smaller the difference between the velocities of the fuel particles and the gas flow (a mixture of air and combustion products) [13]. Small particles used do not deviate from the current line of their carrier medium [13]. Therefore, the heating of fuel particles is carried out mainly as a result of radiation exposure. Convective heat fluxes to the surface of fuel particles in the furnace medium are negligible compared to radiant ones [13]. Therefore, in experiments, stationary air heated to high temperatures, was used as a heating source of fuel particles. The fuel sample was placed above the combustion chamber at a distance of 1–2 centimeters on a special flat holder [13]. The calculated amount of fuel particles was about 80 to 100 pieces. The resulting mixture of fuel particles was discharged into the furnace at a certain point in time. This moment was the starting point of the ignition time [13]. Simultaneously with the introduction of the fuel sample into the combustion chamber, video recording began using a high-speed video camera (image format – 1024×1024 pixels, frame rate - up to 100,000 per second). Ignition delay time was considered as the time from the moment of first particles to enter the furnace until the glow appeared (of first particle or group of particles), corresponding to the beginning of the combustion process [13]. Experiments for each fuel mixture were carried out at least five times, the
results of the experiments demonstrated good repeatability, systematic errors were less than 2 %, and random errors were less than 3.5 % [13].

3. Results and discussion
The results of the technical analysis are shown in Table 1.

Table 1. The results of analysis of the technical characteristics of initial fuel components and mixed fuels based on them (calorific value, moisture content, ash content and volatile yield).

| Fuel (wood/coal_deposit), % | Calorific value, Q, MJ/kg | Technical analysis, % |
|---------------------------|---------------------------|-----------------------|
| 100 / 0                   | 21.73                     | 5.35                  | 0.29                  | 80.25                  |
| 0 / 100_Maikuben          | 24.75                     | 5.17                  | 7.61                  | 50.46                  |
| 10 / 90_Maikuben          | 24.26                     | 5.13                  | 4.22                  | 53.00                  |
| 25 / 75_Maikuben          | 23.97                     | 5.98                  | 3.22                  | 60.49                  |
| 50 / 50_Maikuben          | 22.72                     | 6.57                  | 2.05                  | 71.13                  |

Analysis of the experimental results allows concluding that the addition of wood biomass to coal from the Maikuben deposit leads to a significant reduction in the ash content of the mixed fuel by 73.1 % with a wood fraction equal to 50 % and a moderate reduction in calorific value (by 8.2 %) with the same concentration of biomass in the mixed fuel.

Figure 2 shows the results of experimental determination of ignition delay times for mixed fuels based on fine lignite and crushed wood processing waste.

Figure 2. Dependence of the ignition delay time of floating particles based on the Maikuben coal, wood and fuel mixtures on their basis on the medium temperature at different concentrations of wood components: 1 – homogeneous coal; 2 – 90% coal mixture; 3 – 75% coal mixture; 4 – 50% coal mixture; 5 – homogeneous wood.

The analysis of Figure 2 reveals that the biomass mixed with the coal of the Maikuben deposit decreases the temperature of the ignition processes. An increase in the proportion of wood in the mixture to 25 % is found to start the ignition processes of coal at a temperature of 500 °C (18.02 % lower), and at a temperature of 600 °C (24.65% lower). With an increase in temperature up to 800°C, the ignition processes occur intensively in the same delay time interval, both for homogeneous coal and for mixed fuels.

Conclusions
In accordance with the results of experimental studies, it may be concluded that the effective concentration of wood biomass (waste from the wood processing of the Tomsk LPC), which
contributes to reducing the ignition delay time of lignite from the Maikuben deposit by 25%, is the most effective in the temperature range from 500°C to 600°C.

The obtained research results allow us to reasonably assume that the use of wood biomass in a mixture with Maikuben coal will significantly reduce the temperature of combustion beginning of this coal type.

Acknowledgments
The study was performed with financial support of the RFBR grant No. 18-29-24099.

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