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Research Paper

CHARACTERISTICS OF ALCOHOL-COAL-WATER SLURRIES SPRAYING

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Abstract

The aim of this work is to substantiate the efficiency of ethyl or isoamyl alcohol application as the third component of coal-water fuels based on the results of experimental study of coaxial spraying. Studies of alcohols influence on spraying characteristics of coal-water fuels can rarely be found in the literature. Instantaneous fields of fuel droplets velocities in several cross-sections of the jet were determined using Particle Image Velocimetry method. Interferometric Particle Imaging method was used to determine droplets distribution by size in the jet of sprayed coal-water fuel. It was experimentally established that substitution of water (no more than 3 % by weight) in the composition of coal-water slurry by fairly typical alcohols leads to decrease in droplet velocities of alcohol-coal-water slurries in comparison with conventional coal-water fuel by 15–18 %. Concentration of sufficiently small fuel droplets (up to 200 microns) increases by 13.4±0.2 % and by 6.6±0.2 % during atomization of alcohol-coal-water slurries with addition of ethyl and isoamyl alcohol, respectively. Introduction of no more than 5 % by weight of the studied alcohols into the coal-water slurry will reduce the cost of fuel by 15–73 % in comparison with fuel oil. Influence of small additives of ethyl and isoamyl alcohol in the composition of coal-water fuel on spraying characteristics proves the possibility of efficient application of such three-component slurries in thermal power engineering. The results obtained are of practical significance, since they illustrate the possibility of reducing the ignition delay time for droplets of alcohol-coal-water slurries after they are sprayed in the furnaces of boiler units.

Keywords: Spraying, coal-water fuel, alcohols, droplet, velocity.

1. Introduction

Global coal reserves significantly exceed the volumes of other fossil fuels, such as gas and oil [1]. At the same time, low-quality coals, project fuels with organic additives [1] or expensive fuel oil are often used at energy facilities. This is the reason for the decrease in technical and economic indicators of the power plants [1]. In this regard, coal-water fuels (CWF) are an alternative to the project fuel (for example, fuel oil or coal dust) [2]. However, coal-water slurries are not widely used at thermal power plants (TPP) as the main fuel. A promising option is to use them as fuel at existing or designed low-power thermal facilities – boiler houses. This is usually for reducing fuel costs, and in some cases the anthropogenic impact on the environment [3].

One of the problems holding back coal-water slurries implementation is formation of sufficiently large (more than 1 mm) CWF droplets in the process of coaxial spraying, which results in their late ignition [4]. Results of numerous experimental and theoretical studies of multicomponent fuels atomization in the furnaces of steam and hot water boilers have been published in recent years in order to reduce the characteristic size of droplets of sprayed fuels. It was found [5] that droplets of sprayed coal-water fuel rotate, deform, and collapse when moving. Studies

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of fuel single droplet atomization in a turbulent jet [6] have shown that a single droplet with initial diameter of about 1 mm is atomized into 47 subsequent droplets during a series of crushing operations under conditions of such jet. It was found that decrease (by 7–15 %) of surface tension coefficient contributes to intensification of atomization of the initial droplet with initial characteristic size from 700 microns to 1.5 mm into smaller ones (less than 300 microns).

The paper [7] presents the results of experimental studies of secondary atomization of droplets formed during spraying liquids (sludge – 10 % by weight of coal, 10 % by weight of transformer oil, from 80 to 90 % by weight of water; emulsions – 10 % by volume of water and 90 % by volume of transformer oil or diesel fuel; compositions of heptane-hexadecanes – 34–66 % by volume). Four characteristic stages of droplet crushing were analyzed in [7]: collisions with each other; with a solid surface; with a gas flow; and micro-explosive atomization.

The results of experimental studies of the rheological properties effect on coal-water slurry spraying are presented in [8]. It was established that aerodynamic force causes the liquid to deform and collapse during coaxial spraying of two-component coal-water fuel. The research results showed that viscosity of coal-water slurry has significant effect on the mechanism of CWF spraying. In particular, the number of droplets during secondary atomization of high-viscosity coal-water fuel is less than after spraying less viscous slurry.

The authors of [9] experimentally studied atomization of ecologically promising coal-water slurries. It was found that the most promising composition in terms of environmental characteristics and relative indicators is based on 90 % wet coal sludge and 10 % rapeseed oil. Stable composition under intense microexplosive atomization was determined. This is 9 % filter coal sludge, 10 % water and 81 % rapeseed oil. At the same time, microexplosive atomization of the parent droplet provides significant increase in the surface area of the sludge.

It was found in [10] that addition of high-carbon and low-cost waste into CWF and coal-water slurries containing petrochemical products provides maximum overall efficiency of slurries. However, high-quality and expensive components (for example, fuel oil) without heating, even in small quantities, lead to a significant worsening of CWF characteristics after spraying.

The authors of the above works studied the characteristics of coal-water fuel droplets after spraying, which is very important for the development of advanced technologies for energy production and application. However, data on the influence of alcohols in the composition of coal-water slurries on the jet characteristics in the process of coaxial spraying are not available in the literature. Researchers paid attention to methanol as a component of coal-water fuel [11]. Mass concentration of alcohol in such slurries was about 30 %. That is why such slurries are essentially not coal-water fuels. They can be called coal-alcohol fuels with water addition. Such fuels cannot be used in the real heat power industry for several reasons. The main reason is significantly higher (by 15–70 %) cost of coal-alcohol fuels compared to coal-water fuels. The second (no less important) is high fire hazard of coal-alcohol fuels.

Therefore, experimental studies of the effect of relatively small additions (no more than 3 % by weight) of ethyl and isoamyl alcohol on the characteristics (velocity, size and number of droplets) of CWF jet after spraying presented in this article are new and relevant. The purpose of this work is to substantiate the efficiency of ethyl or isoamyl alcohol application as the third component of coal-water fuels based on the results of experimental studies of coaxial spraying.

2. Methods

2.1. Fuel preparation technology

The main stages of slurry fuel preparation are shown in Figure 1. The studied ACWF and CWF were prepared on the basis of lignite from the Kansk-Achinsk coal basin. At the first stage, the coal was crushed in jaw crusher (the particle size at the outlet is no more than 30 mm), after which it was dry ground in disintegrator. Then the coal was sifted using a vibrating screen with selection of material with fraction of up to 200 microns. Wet grinding was carried out in a ceramic drum with a volume of 3 liters at a mass ratio of coal and grinding bodies of 1:1 for 1 hour.

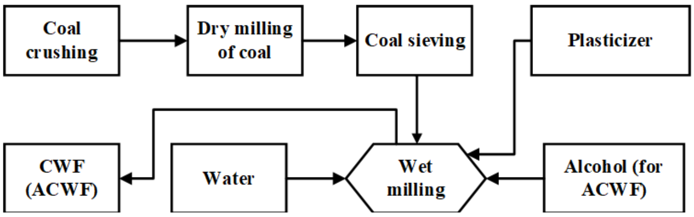


Fig. 1. Stages of fuel slurries preparation

Water, ethyl and isoamyl alcohol at 293 K were used for preparation of coal-water slurries. Their main properties are shown in Table 1. The fuel temperature was 293±1 K during the experiments. Tables 1–3 present characteristics of liquid components and coal, as well as compositions of the studied fuels.

Table 1. Parameters of liquid slurry components

Component	Density, kg/m^3	Dynamic viscosity, 10^{-3} Pa·s
Ethyl alcohol	785 [12]	1082 [12]
Isoamyl alcohol	808 [13]	2957 [14]
Water	997 [15]	890 [15]

Table 2. Coal characteristics

Ash content A^d, %	8.0
Volatile content V^{daf}, %	42.5
Carbon content, % daf	72.1
Hydrogen content, % daf	5.8
Total percentage of oxygen, nitrogen and sulfur, % daf	22.1
Humidity, %	9.0

Table 3. Coal-water slurries

Composition, №	Coal	H_2O	NaOH	C_2H_5OH	$C_5H_{12}O$
	%, by weight				
1	50	49	1	–	–
2		46		3	–
3				–	3

2.2. Visualization methods

Techniques for high-speed visualization of jet characteristics (droplet velocities, sizes, and concentrations) of sprayed coal-water fuels are similar to those described in [16]. Registration of the structure of the steady flow of sprayed fuel slurries and their velocity was performed by the PIV method (Particle Image Velocimetry). It is a measurement technique that captures velocity fields in less than a second. The principle of this method is that two images are captured with a certain delay. The particle velocity is determined by dividing the resulting displacement by the known flow time. Illumination of the sprayed fuel jet was performed by a laser sheet oriented along the fuel cone axis. The laser sheet was created by Beamtech Vlite-200 double pulse laser. Registration was carried out with ImperX Bobcat B2020 camera and a Nikon lens with a focal length of 50 mm and a viewing angle of 46°. Synchronization of the laser and the camera was carried out by SP-2.0 PS synchronization unit. Experimental studies of the slurry fuel spraying were carried out using ActualFlow software developed by Sigma-Pro (Novosibirsk). The obtained images were processed using the same software. A standard cross-correlation method was used to determine the droplet velocity of the slurry fuel. The calculation was carried out by the method of direct calculation of convolution in order to avoid undesirable effects inherent in the Fourier transform (in particular, the systematic error in determining particles displacement).

The IPI (Interferometric Particle Imaging) method was used to determine particle size of the sprayed stream. This method uses special optics that refract the laser light, creating interference fringes. To do this, a special device is added in front of the camera lens to obtain interference fringes – an optical compression unit for interference fringes. The processing of the obtained data was also carried out using ActualFlow software.

Measurement error, taking into account possible sources of error (such as: local velocity gradient; droplet displacement; optical effects, etc.), did not exceed 8 % for PIV similarly to [16] and 2 % for IPI method. Schematic diagram of the stand for jet recording of coal-water fuels during coaxial spraying is shown in Figure 2.

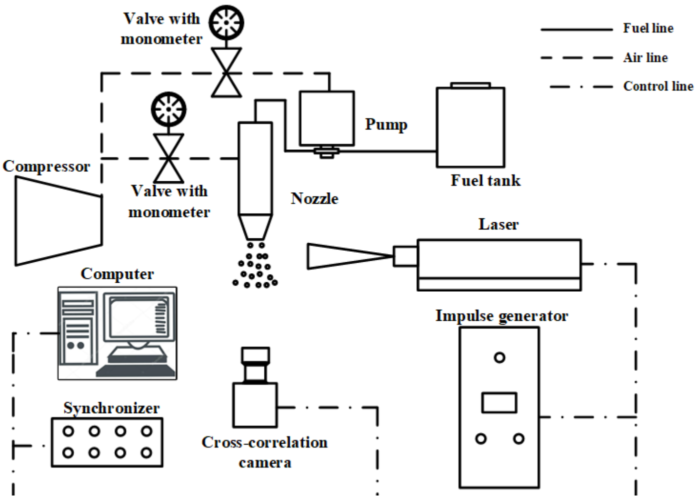


Fig. 2. Schematic diagram of the stand for coal-water fuel atomization recording

At least 50 measurements were performed for each researched composition of coal-water slurry for IPI method. The total distribution of fuel droplets ($\sum n_i$) on all images was normalized to the total number ($\sum K$) of identified droplets during results processing

$$N = \frac{\sum n_i}{\sum K} \cdot 100\ \%.$$

2.3. Experimental setup

Experimental studies of the effect of ethyl and isoamyl alcohol in the composition of CWF on the characteristics of the spraying process were performed in aerodynamic simulator of the combustion chamber of power boiler (Figure 3, a). Coal-water slurry was fed from fuel storage tank using diaphragm pump with pneumatic drive. Air supplied by compressor to the coaxial nozzle with internal mixing was used as the spraying agent (Figure 3, b). The nozzle outlet diameter was 3 mm. Coal-water fuel coaxial spraying with alcohol addition is shown in Figure 3, c.

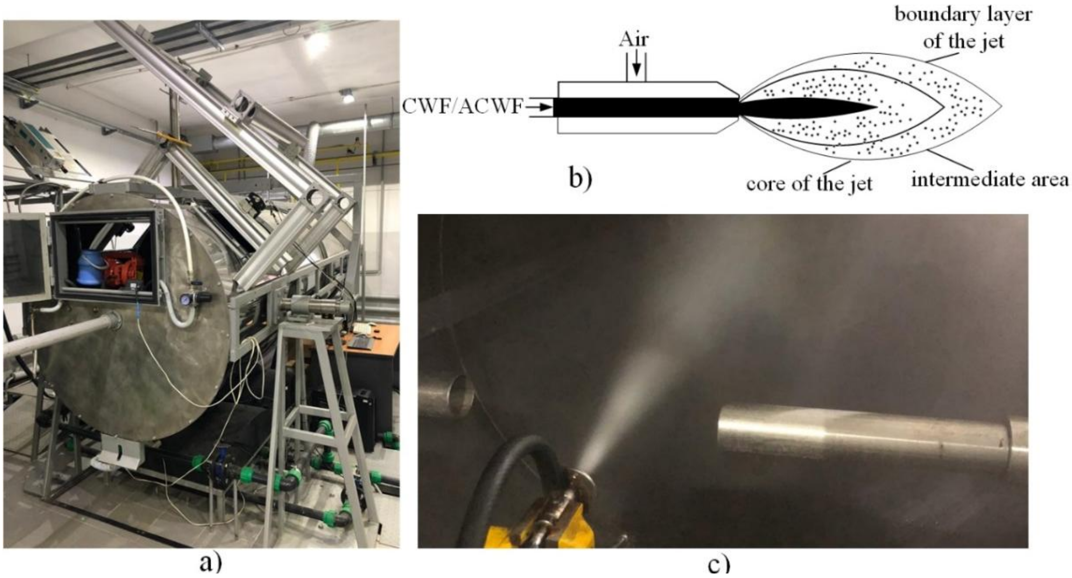


Fig. 3. Aerodynamic simulator of the combustion chamber: a) photo of the stand; b) CWF/ACWF spray scheme; c) spraying process

Pressure of air and slurry fuel was 0.28 and 0.3 MPa, respectively, in order to exclude the effect of «choking» of the viscous slurry by air in the nozzle and further along the fuel path during the experiments. Time of the experiment for each composition was 100–120 seconds. This time interval is sufficient for formation of a stable jet structure. Dimensions of the study area were: in the longitudinal direction of the jet – 0.1 m, perpendicular to the axis – 0.05 m. The experiments were performed under well-reproducible conditions at an ambient temperature of 293±1 K and a relative humidity of 65±3 %.

2.4. Estimation of measurement uncertainties

The algorithm for calculating random errors was developed in accordance with the mathematical apparatus of error theory [17, 18]. Several experiments were performed under the same conditions for each composition of coal-water fuel to estimate random errors. The arithmetic mean of the measurement results was taken as the most probable value of the studied value:

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i.$$

The standard deviation (SD) of the measurement results was calculated using the formula:

$$S_{\bar{x}} = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \bar{x})^2}{(N-1)}},$$

here N is the number of experiments.

It is known [17, 18] that random errors are the result of uncontrolled insignificant processes. Therefore, it is difficult to accurately determine the range of changes in the measured value. It can only be calculated with a certain confidence probability of R_e. To estimate the errors of measurement results in experiments, a confidence probability was assumed equal to 0.95. With this confidence probability, we can assume that the true value of x does not differ from the value of the arithmetic mean by more than $\pm\Delta x$. The Student coefficient value was selected from the tables in [17].

Confidence interval of random measurement error:

$$\Delta x_{ran} = \tau_{\alpha}(n) \cdot S_{\bar{x}}.$$

Absolute measurement error including random and instrumental errors:

$$\Delta x = \sqrt{\left(\frac{2}{3}\Delta x_{syst}\right)^2 + \Delta x_{ran}{}^2}.$$

Relative error of measurement:

$$\varepsilon = \frac{\Delta x}{\bar{x}} \cdot 100\%.$$

Final result of the measurement:

$$x = \bar{x} \pm \Delta x.$$

The 2/3 multiplier was used to account for the confidence probabilities of determining random and instrumental errors. The random error was calculated for the confidence probability R_e=0.95, and the instrumental error – for the confidence probability R_e=1.

3. Results and discussion

The main characteristics of the jet necessary for analysis and comparison were obtained as a result of experimental studies of coaxial spraying of coal-water slurries with relatively small additions of ethyl and isoamyl alcohol (Table 3) and conventional CWF. Those characteristics are distribution of droplets by velocity and size, and their concentration in the study area. Analysis of the experimental results (Figure 4) showed that velocity distribution of droplets of the studied slurries in several characteristic cross sections of the jet – at distances of 25 (*I*), 50 (*II*), 75 (*III*) and 100 (*IV*) mm from the nozzle – are different. It was established that the maximum values of the fuel droplet velocities are reached directly along the jet axis. Figure 4 shows velocity distribution of coal-water fuel droplets prepared on the basis of fairly typical lignite in four cross-sections of the jet.

Reasons for the decrease of velocity values of CWF and ACWF droplets along the axial coordinate during spraying are coagulation of the droplets, their rotation and destruction due to aerodynamic drag in the external environment. In this case, trajectory of the slurry droplets in the jet changes, and diameter of sprayed fuel jet increase. Velocity of droplets in the study area (25–100 mm in the axial coordinate) decreases by 9.4±0.4 % for typical CWF, by 15±0.4 % for coal-water fuel with ethyl alcohol, and by 10.5±0.4 % for the slurry with isoamyl alcohol (Figure 4).

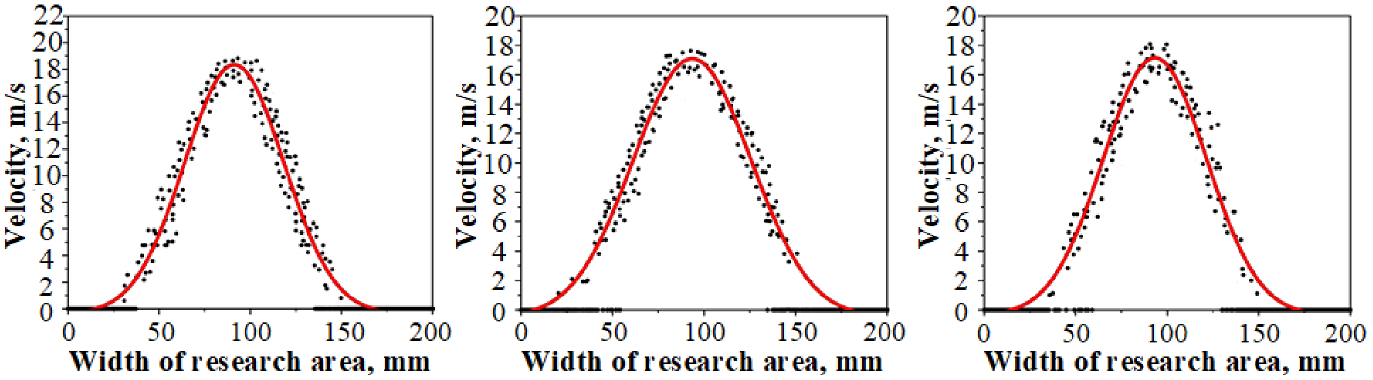
Changes in the velocity of droplets of the studied coal-water fuels along the axial coordinate in the jet core are shown in Figure 5.

Dependences analysis in Figure 5 shows that relatively small (no more than 3 % by weight) addition of alcohol (ethyl or isoamyl) has significant effect on the velocity of fuel droplets in the jet. It can be concluded on the basis of experimental data that substitution of water in coal-water fuel by relatively typical alcohols leads to a decrease (by 15–18±0,4 %) of droplets velocity in comparison with typical CWF. This is due to viscosity increase of ACWF with ethyl alcohol by 2 % and ACWF with addition of isoamyl alcohol by 5 %. On the one hand, viscosity increase of sprayed fuels affects the size of secondary droplets (the concentration of large droplets increases). On the other hand, the larger (by 4–7 %) values of the densities ratio of environment and the studied ACWF contribute to increase in the number of small fuel droplets in comparison with conventional coal-water slurry.

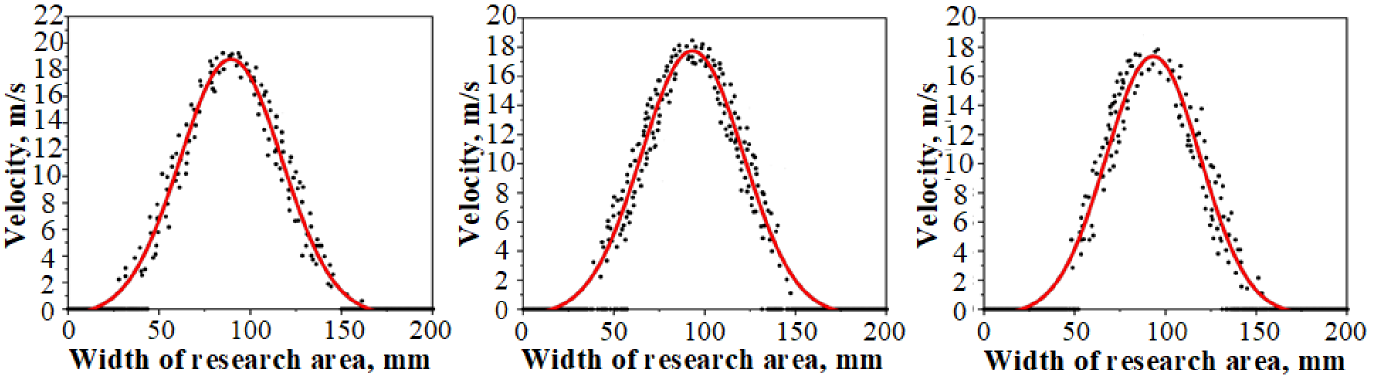
Processing of the recorded results using the IPI method allowed obtaining information about distribution of identified droplets of the studied coal-water slurries by size during atomization by air (Figures 6–8). Figure 6 shows distribution of droplets by size *N* in the study area from 25 to 50 mm along the axial coordinate from the nozzle. It was found that relatively small (no more than 3 % by weight) addition of relatively typical alcohols in the composition of CWF contribute to the formation of a smaller number of fuel droplets with a characteristic size of up to 100 microns (by not more than 2.4 %) for CWF with ethyl alcohol. However, a larger number (by not less than 1.5 %) of such droplets was recorded for CWF with isoamyl alcohol in comparison with conventional coal-water fuel. The tendency to increase is typical for droplets concentration with diameter of 100 to 200 microns. The number of such fuel droplets is greater by 16.1±0.2 % for CWF with ethyl alcohol and by not less than 3.4 % with isoamyl alcohol in comparison with conventional coal-water fuel. The total percentage of droplets with a characteristic size of up to 400 microns is 77.1±0.2 % for conventional CWF, 83.5±0.2 % for coal-water fuel with ethyl alcohol and 79.4±0.2 % C for CWF with addition of isoamyl alcohol. No more than 18±0.2 % of droplets with diameter of more than 400 microns is typical for both conventional coal-water fuel and slurries with alcohol additives.

The results of experiments in the study area at a distance of 75–100 mm from the nozzle shown in Figure 7 illustrate small advantage of coal-water fuel with typical alcohols in comparison with conventional CWF. 22.5±0.2 % more droplets with characteristic size of up to 100 microns are formed in the process of spraying CWF with ethyl alcohol and 11.4±0.2 %

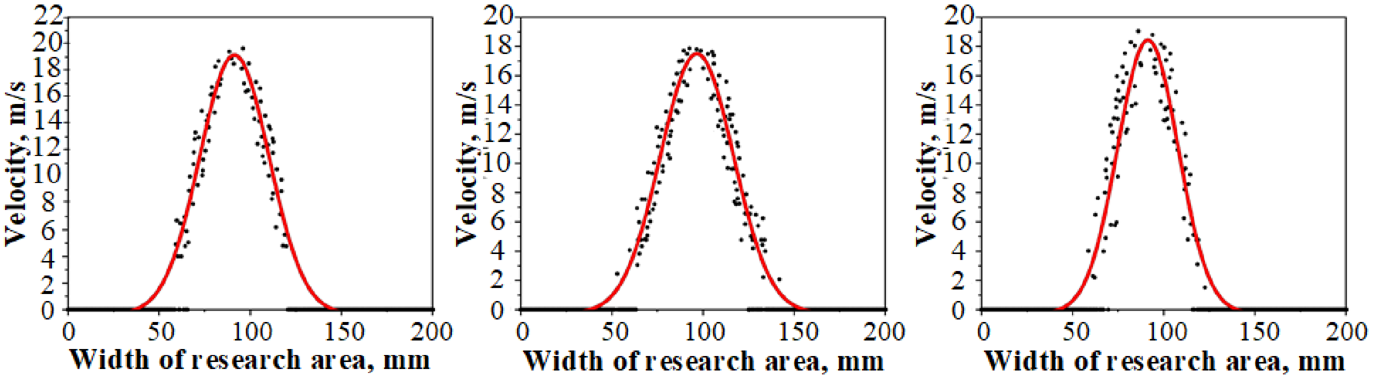
more droplets of coal-water slurry with addition of isoamyl alcohol in comparison with conventional CWF. The number of identified fuel droplets with a characteristic size from 100 to 200 microns is less by 3.2±0.2 % for CWF with ethyl alcohol and by 4.9±0.2 % for CWF with isoamyl alcohol.



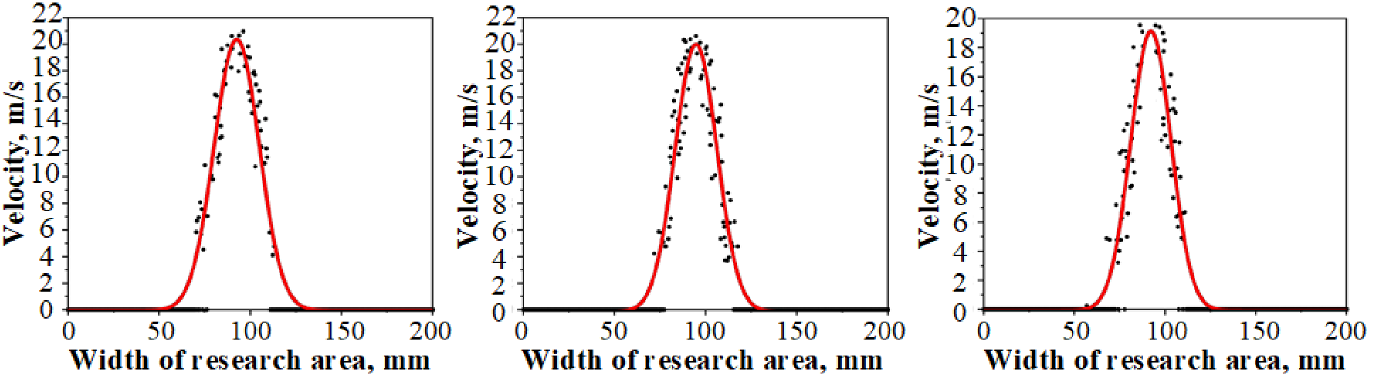
Jet cross-section - *IV*



Jet cross-section - *III*



Jet cross-section - *II*



Jet cross-section - *I*

CWF

CWF+3% C_2H_5OH

CWF+3% $C_5H_{12}O$

Fig. 4. Velocity distribution of fuel droplets in cross sections

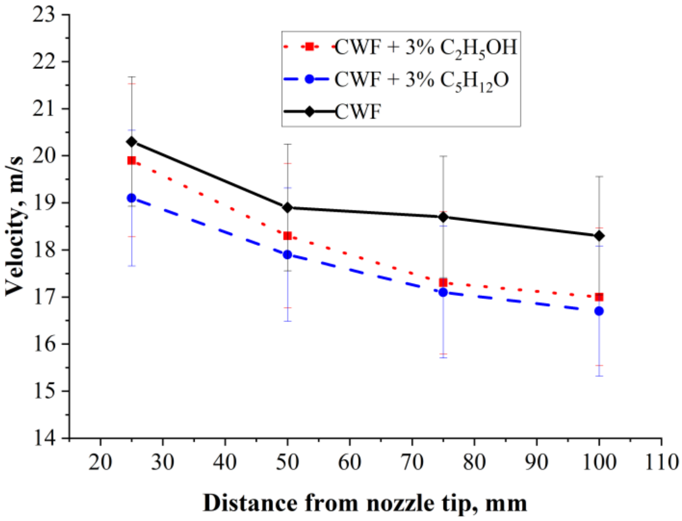


Fig. 5. Velocity distribution of CWF droplets in the jet core

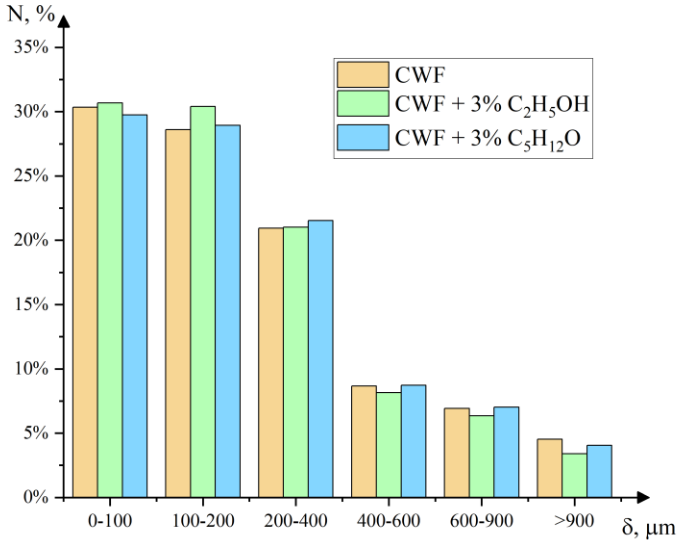


Fig. 6. Distribution of fuel droplets by size in the study area along the axial coordinate – 25–50 mm. N – concentration of fuel droplets, %; δ – range of droplets sizes, μm

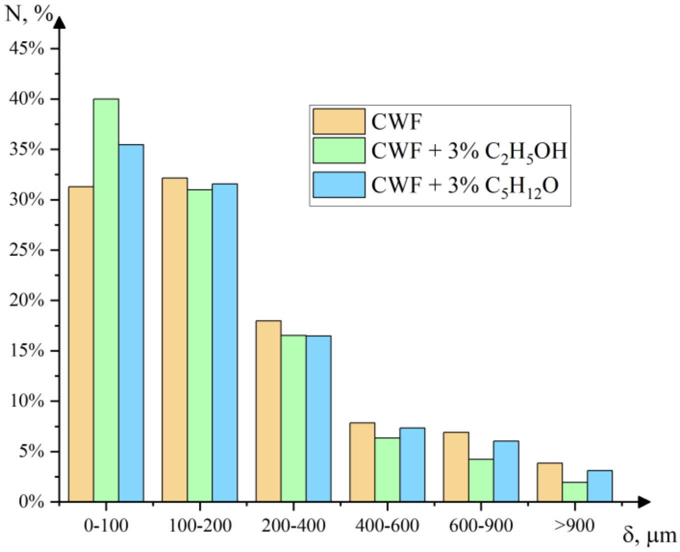


Fig. 7. Distribution of fuel droplets by size in the study area along the axial coordinate – 75–100 mm. N – concentration of fuel droplets, %; δ – range of droplets sizes, μm

In general, distribution of droplets of sprayed fuels by size in the study area (from 25 to 100 mm along the axial coordinate) is shown in Figure 8. Concentration of small CWF droplets (up to 200 microns) increases by not less than 7 % with addition of ethyl alcohol and not less than 2 % of CWF with addition of isoamyl alcohol in comparison with conventional CWF.

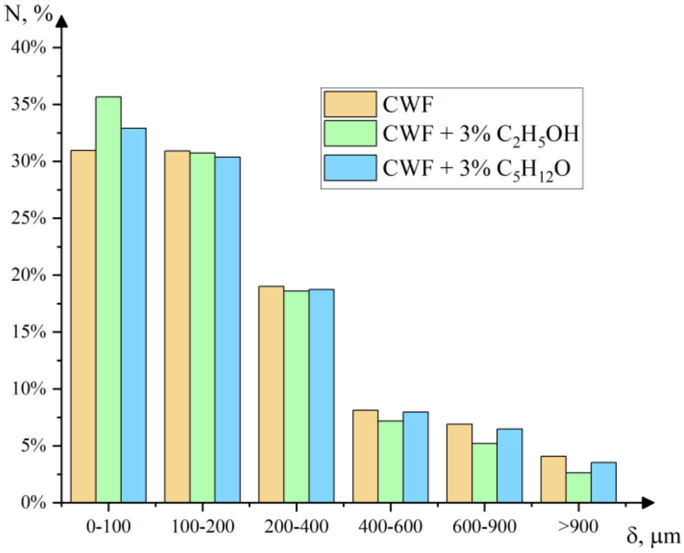


Fig. 8. Distribution of fuel droplets by size in the study area along the axial coordinate – 25–100 mm. N – concentration of fuel droplets, %; δ – range of droplets sizes, μm

Analysis of experimental results allows drawing several conclusions. First, influence of alcohols on ACWF spraying contributes to the formation of larger (by 7±0.2 %) number of small droplets in comparison with conventional coal-water fuel. Second, their ignition, as it is known [4], occurs at significantly lower delay times compared to large (more than 1 mm) droplets.

Increase in the number of small fuel droplets during spraying due to the introduction of additional liquid fuel component (alcohol) into CWF will increase surface area of evaporation by several times. Such great changes in the surface area of liquid evaporation in the process of coaxial spraying significantly intensify the processes of heat and mass transfer, phase transitions. As a result, rates of chemical reactions between the fuel and the oxidizer will increase.

Comparing the results of experimental studies of coaxial spraying of coal-water fuel with relatively small addition of ethyl and isoamyl alcohol with [19], we can conclude about the advantages of such fuels from the energy point of view in comparison with a typical two-component CWF. Analysis of the results of [19] showed positive effect of additional electrostatic spraying of coal-water fuel. Atomization of the slurry is accompanied by impressive energy consumption (up to 20 kV). On average, 25–35 % more fuel droplets of small (less than 200 microns) sizes are formed in comparison with the studied CWF. Addition of alcohols to the composition of CWF eliminates additional electricity costs for spraying. It allows reducing the energy cost of fuel atomization by 8–14 % in comparison with [19].

Comparison of the obtained results with [20] also allows drawing a conclusion about the advantage of alcohol-coal-water slurries in comparison with typical coal-water fuel. Influence of boiling of the sprayed slurry studied in [20] showed positive result. The resulting cone-shaped jet mainly consists of small droplets (up to 200 microns) located on the longitudinal axis and large ones (more than 500 microns) at the jet boundaries. This method of spraying requires additional energy costs for fuel heating. Additional heating of coal-water fuel to the saturation state will increase the cost for combustion preparation of such slurry by 17–20 % compared to a typical coal-water fuel and by 6–11 % compared to the studied alcohol-coal-water slurries. These advantages of coal-water fuels combined with alcohols make them competitive in terms of energy and economic criteria relative to two-component fuels sprayed with additional energy costs.

Most likely, addition of ethyl or isoamyl alcohol to the composition of coal-water slurry leads to a weakening and breaking of the bonds between water molecules. This manifests itself in increase of the liquid evaporation rate from the surface of fuel droplets. This causes, in its turn, their size decrease during atomization of coal-water slurries with alcohol additives in comparison with conventional two-component coal-water fuels. The experimental results presented in Figures 6, 7 in the form of size distribution of the studied fuels droplets in the areas remote from the nozzle along the axial coordinate (25–50 and 75–100 mm) confirm this conclusion. The number of large ACWF droplets studied (200 microns or more) is reduced by 18.6±0.2 % for coal-water fuel with addition of ethyl alcohol and by 12.9±0.2 % for CWF with isoamyl alcohol in comparison with conventional coal-water fuel.

The results of experiments showed that introduction of ethyl or isoamyl alcohol as the third component in the composition of coal-water fuel improves the jet characteristics after spraying. It is obvious that adding alcohol to traditional coal-water fuel will increase its cost and, consequently, increase the price of thermal or electrical energy. At the same time, the option of using alcohol-coal-water slurry as an alternative fuel for boilers operating on fuel oil is attractive from an economic point of view. The authors tried to compare the cost of 1 kg of alcohol-coal-water fuel with addition of different alcohol types with M-100 and TKM-16 fuel oils used as boiler fuel. The results are presented in Table 4. Water costs were not taken into account in the cost calculation. Prices for ACWF components (coal [21], alcohols [22]) and fuel oil are mid-market.

Table 4 shows a comparison of cost of ACWF prepared with addition of isoamyl or ethyl alcohol with fairly typical fuel oils used as the main fuel in boiler houses. It illustrates superiority of alcohol-coal-water slurry. Introduction of no more than 5 % by weight of the studied alcohols into CWF reduces the cost of boiler fuel by 15–64 % in comparison with M-100 and TKM-16 fuel oils. This significant advantage makes ACWF a competitive fuel compared to fuel oil.

Table 4. Cost of coal-water fuel in comparison with fuel oil

Weight, kg	Price of coal per 1.0 kg, $	Price of M-100 fuel oil for 1.0 kg, $	Price of TKM-16 fuel oil for 1.0 kg, $	Weight, kg	Price, $	ACWF price, $	Increase in the price of ACWF in relation to CWF, %	Increase in the price of ACWF in relation to M-100 fuel oil, %	Increase in the price of ACWF in relation to TKM-16 fuel oil, %
Coal		Fuel oil		Isoamyl alcohol					
1.0	0.039	0.17	0.09	0.003	0.004	0.043	9.30	–74.71	–52.22
				0.005	0.007	0.046	15.22	–72.94	–48.89
				0.008	0.011	0.05	22.00	–70.59	–44.44
				Ethyl alcohol		–			
				0.003	0.022	0.061	36.07	–64.12	–32.22
				0.005	0.037	0.076	48.68	–55.29	–15.56

				0.008	0.059	0.098	60.20	–42.35	–8.89

Experiments have shown that characteristics of the jet after alcohol-coal-water fuels spraying are improved in comparison with traditional coal-water fuel. At the same time, it is known [23] that coal production technologies are accompanied by the formation and accumulation of coal sludge (filter cake). Using them as a base or component of coal-water fuel is one of the most promising ways to dispose such waste [24]. The results obtained are the basis for further theoretical and experimental studies of CWF spraying based on the waste from coal mining enterprises with small-weight additives of alcohols (no more than 10–12 %). The cost of such alcohol-coal-water fuels is comparable to the cost of typical two-component coal-water fuel, and in some cases it is significantly lower.

4. Conclusion

Experimental studies of the effect of small-weight (no more than 3 %) alcohol additives on the jet characteristics in the process of coaxial spraying of coal-water fuels have been performed. Water replacement by relatively typical alcohols in the composition of coal-water slurry leads to decrease in the droplet velocities by 15–18±0,4 %. It was found that concentration of fuel droplets up to 200 microns in size increases by 7±0.2 % during atomization of CWF with addition of ethyl alcohol in comparison with conventional coal-water fuel. Concentration of such droplets raises by 2±0.2 % during atomization of CWF with addition of isoamyl alcohol in comparison with conventional coal-water fuel. The number of sufficiently small (up to 100 microns) fuel droplets increases by 13.4±0.2 and 6.6±0.2 % for CWF with addition of ethyl alcohol and isoamyl alcohol, respectively. Relatively small additions of alcohols to the composition of coal-water slurry leads to weakening of the bonds between water molecules. It is manifested in increase in rate of liquid evaporation from the surface of fuel droplets. This is the reason for their size reduction during atomization of coal-water slurries with alcohol in comparison with conventional two-component CWF. Introduction of no more than 5 % by weight of the studied alcohols into the composition of CWF reduces the cost of boiler fuel by 15–73 % in comparison with fuel oil. The obtained experimental data substantiate the efficiency of ethyl or isoamyl alcohol addition to the composition of coal-water fuel. It can be used in the analysis of optimal ignition conditions for alcohol-coal-water slurries. There are studies on coal-water fuel spraying, but addition of alcohols is not widely studied up to date. That is why the results obtained are unique and can be used for mathematical modelling or design of power boilers operating on alcohol-coal-water fuels.

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