Applying composite fuels based on coal and finely dispersed wood in heat power engineering

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Abstract. Results of experimental research of thermal decomposition of composite fuels based on 2B brown coal (Borodinskoe deposit) and wastes of timber industry (finely dispersed wood) are presented. Elemental composition of researched fuels has been defined and technically analyzed. Kinetic constants have been calculated within Arrhenius model of the first order. It has been determined that with an increase of wood concentration up to 50% in composite fuel, its energy characteristics decrease by less than 2%, the maximum temperature of fuel thermal decomposition reduces by 9%, while SO_x and NO_x yield reduces by 50%, and fly ash – by 75%. An effective composite fuel composition of 50%/50% has been established. Results of performed experimental studies illustrate possible applications of composite fuels based on brown coal and wood at thermal power plants.

Introduction

The share of the world coal reserves in the Russian Federation today is 19% and its application at TPPs is 26% [1]. For many thermal power plants coal is imported, which leads to a 1.5-2 times increase in consumer cost of energy resources (depending on the region). The necessity of reducing the share of imported resources in regional fuel and energy sector is justified in Energy Strategy of Russia for the period until 2035. Requirements of this strategy imply an up to 4.5% increase of production volumes of thermal and electric energy using renewable energy sources. It is known [1] that wood is a renewable source of energy, if rationally used, and its reserves in Russia exceed 80 billion cubic meters. Wastes of its processing exceed 30 million cubic meters per year. At the same time, liquid and solid fuels for local thermal power plants are supplied to areas with a large potential of wood biomass. Interest in power engineering application of biomass is caused by stricter environmental requirements and standards and rising prices of primary energy sources. Versatility and availability of carbon-neutral wood bio-resource that does not aggravate global warming process is an important argument in favor of this fuel type application throughout the world [2-3]. To reduce negative impact on the environment of coal combustion products [4], application of environmentally cleaner composite fuels (mixture of wood and coal) is considered to be promising [5].

1. Experimental setup

Preparation of test samples was conducted in accordance with GOST 10742-71 and was followed by sieving in accordance with GOST 3306-88. Particle size of researched coal powders was less than 80 μm, and that of sawdust was less than 200 μm. Crushed coal samples of 2B grade (Borodino deposit) and waste of timber industry (fine dispersed wood) have been analyzed and elemental analysis of each

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fuel has been conducted separately using JEOL JCM-6000 scanning electron microscope (SEM) [6]. Elemental composition of each component for sample forming of composite fuels (coal and wood) is presented in Table 1.

Table 1. Elemental composition of researched fuel samples, %wt.

Elemental composition	Brown coal	Wood
C	71	58
H	6,1	6,9
O	19,3	28,3
N	3,4	6,7
S	0,2	0,1

Mixtures of grounded coal and wood particles were loaded at certain mass concentrations into galvanized drum of Pulverisette 6 planetary mill with spherical grinding bodies with a diameter of 5 mm and weight ratio of 1:1. Mixing was realized for seven minutes at rotation speed of 500 rpm [7]. Then, technical analysis of obtained composite fuel was performed (Table 2).

Table 2. Technical analysis of researched composite fuels

Material	Calorific value, Q, MJ/kg	Moisture content, W,%	Ash content, A,%	Volatiles yield, V^{daf}, %
Wood	21.73	6.96	0.29	80.25
2B brown coal	23.72	8.25	7.42	43.39
10 % – Wood, 90 % – 2B	23.68	12.29	4.68	47.93
25 % – Wood, 75 % – 2B	23.44	10.45	4.53	51.7
50 % – Wood, 50 % – 2B	23.35	10.29	3.82	66.17
75 % – Wood, 25 % – 2B	21.67	9.47	2.85	66.72
90 % – Wood, 10 % – 2B	20.66	8.11	1.87	73.75

Analysis of the results shown in Table 2 demonstrates that when concentration of finely dispersed wood increases from 10% to 50%, the calorific value of composite fuels is reduced by less than 2% compared to the initial coal. With an increase of wood concentration up to 90%, the calorific value is reduced by no more than 13%. Based on the foregoing, it can be concluded that the increase of wood concentration to 50% slightly affects energy characteristics of the initial fuel, but ash content of the composite fuel reduces by 48.5% and volatiles yield increases by 52.5%. Increase of wood concentration to 90% leads to a 25% decrease in ash content of the fuel, while 70% increase of volatiles yield is observed.

2. Results and discussion

Kinetic constants of fuel pyrolysis have been determined. Results are shown in Table 3. Activation energy values obtained for researched composite fuels are presented in Figure 1.

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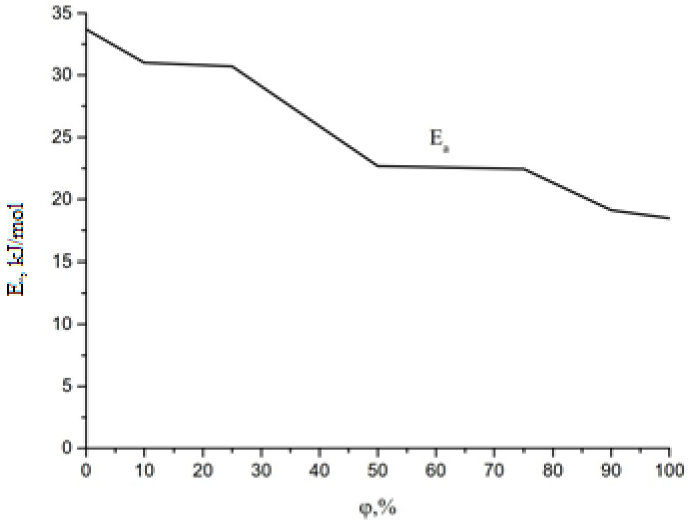

Figure 1. Activation energy during thermal decomposition of composite fuels compared to the initial coal (φ – wood concentration)

Analysis of Figure 1 allows determining that at increasing wood concentration the activation energy of thermal decomposition of composite fuels decreases.

Table 3. Kinetic constants of researched composite fuels pyrolysis

Fuel composition	Parameter	Value
2B brown coal	E_a, kJ/mole	33.7
	Equation of approximating curve	y = -4053.4x - 8.1387
10% – Wood, 90% – 2B	E_a, kJ/mole	31.01
	Equation of approximating curve	y = -3850x - 6.3441
25% – Wood, 75% – 2B	E_a, kJ/mole	30.71
	Equation of approximating curve	y = -3653.8x - 7.3081
50% – Wood, 50% – 2B	E_a, kJ/mole	22.67
	Equation of approximating curve	y = -2726.9x – 9.219
75% – Wood, 25% – 2B	E_a, kJ/mole	22.44
	Equation of approximating curve	y = -2699.3x – 9.322
90% – Wood, 10 % – 2B	E_a, kJ/mole	19.12
	Equation of approximating curve	y = -2300.6x - 10.439
Wood	E_a, kJ/mole	18.47
	Equation of approximating curve	y = -2222.5x - 10.783

Table 3 shows that 50% increase of wood concentration in composite fuel reduces activation energy two times, and 90% increase – six times. Obtained dependences confirm a decrease of the initial temperature of thermal decomposition. In order to compare the negative impact of composite fuel on the environment vs. initial coal, pyrolysis products were analyzed with QMS 403 C Aeolos quadrupole mass spectrometer (add-on of Netzsch STA 449 F3 Jupiter Synchronous Thermal Analysis Unit). Relative concentrations of main anthropogenic gases in pyrolysis products of researched composite fuels compared to the initial coal are shown in Figure 2.

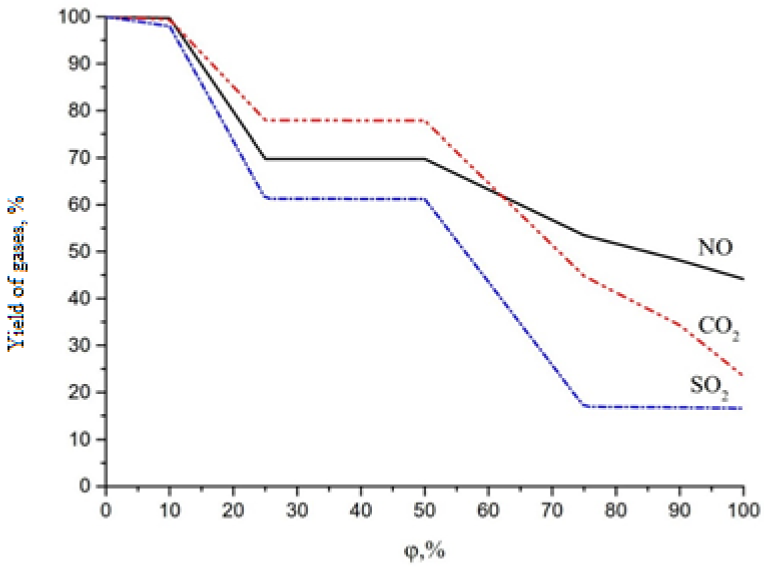

Figure 2. Concentration of released gases during thermal decomposition of composite fuels vs. pure coal (φ – wood concentration)

Figure 2 shows that an increase of wood concentration in composite fuel reduces the release of anthropogenic gases (relative to 100% of anthropogenic gases released by thermal decomposition of pure coal): NO by 51%, CO_2 by 65%, and SO_2 by 83%. The obtained results create prerequisites for substantiating the influence of wood concentration on characteristics of composite fuels based on coal and wood.

Conclusion

The influence of wood concentration on kinetic, energy characteristics and parameters of anthropogenic gases released during thermal decomposition of composite fuel has been determined. Results of the analysis allow classifying composite fuel based on coal and wood by applying in combustion chambers of steam boilers at the stage of composition selection.

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