Ignition of granulated mixed fuel based on lignite and wood waste

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Abstract. Analysis of utilization possibility of sawmill waste when burning pellets in a mixture with coal. Conditions and characteristics of pellets ignition of fuel mixtures based on coal dust and fine wood at various mass concentrations of the components have been experimentally determined. Fuel pellets were made by cold pressing on a hydraulic press. The experiments were carried out in a medium heated to high (from 600 ° C to 800 ° C) temperatures of still air. It was established that increase of wood component proportion in the fuel granule significantly reduces the values of ignition delay times of all studied mixtures based on brown coal of 3B grade. The limit of stable ignition of such fuels is 600 ° C. The obtained results reflect the possibility of using granules of mixed fuels based on crushed coal and wood in the case of fuel-bed combustion in coal-fired boilers, as well as hot water boilers.

1. Introduction

Production of electricity and heat from combustion of coal in the furnaces of hot water boilers is also relevant in the 21st century [1,2]. The use of coal in the world is expected to remain at a high level for the next 50 years or more [3-6]. However, direct combustion of coal at thermal power plants and in the furnaces of boilers of local heating systems entails significant emissions of sulfur and nitrogen oxides, as well as fly ash. In addition to traditional technologies for reducing anthropogenic emissions from coal combustion [7–10], alternative (thermochemical) methods are being sought: the use of coal-water [11], organic coal-water [12], mixed fuels based on coal and biomass (wood) [13-19]. A number of researchers have discovered [20–22] the synergistic effect of harmful emissions reduction from combustion of this type of fuel. A promising direction for solving environmental problems of energy complexes is application of composite fuel pellets based on coal and various bio-waste [23] for combustion in furnaces of local (individual) heating systems.

Addition of fine wood as a component to coal when forming granulated mixed fuel for heat production has an advantage that the carbon biomass is neutral. Wood and its wastes are the most common biological resource [24]. Preparation of mixed fuel pellets can reduce consumption of imported coal through the use of local energy source [25]. Nevertheless, the large-scale power application of such fuels is not yet developed because there is no general theory of formation of their component composition, and physicochemical processes occurring during their combustion are not investigated. Ecological, energy, and technical characteristics of the obtained pelleted mixed fuels, including addition of wood to coal, have not been experimentally studied with sufficient detalization. The results presented in [26 - 28] cannot be the basis for the analysis of processes regularities of fuel mixtures thermal decomposition, with a change in the ratio of wood and coal concentration. Therefore, research in this area is relevant. Analysis of the possibility of creating granulated composite fuels with energy characteristics close to homogeneous coal and significantly better environmental parameters (similar to carbon - neutral) is of high interest.

The purpose of the study is experimental assessment of energy and environmental characteristics of granulated mixed fuels based on coal and timber production wastes.

2. 2. Experimental section

2.1. Experimental section

Brown coal of 3B grade (Balakhtinskoe deposit) was used in experimental studies. The particle size was no more than 80 microns. The second component was sawmill waste (particle size less than 200 microns). Determination of technical characteristics of the studied mixed fuels (calorific value, ash, moisture and volatiles) was carried out after preliminary preparation of both components [29].

Fuel mixtures of coal particles and sawdust were prepared and placed in a galvanized drum of Pulverisette 6 planetary mill with spherical (steel) grinding bodies with a diameter of 5 mm in a mass ratio of 1:1. The mixing process was carried out at rotation speed of 500 rpm for seven minutes [29]. Experiments to determine ignition delay times were carried out in air at temperatures from 600°C to 800°C. Record of processes of ignition and combustion of mixed fuel samples was carried out using a high-speed video camera (image format - 1024 × 1024 pixels, frame rate - up to 105 per second), which provides high sampling of registration results of characteristic times of processes [29]. A temperature limit has been identified for the stable ignition of such fuels. Technical characteristics of the studied mixed fuel samples were determined according to standard methods [29] and are listed in Table 1.

Table 1. The results of elemental composition analysis of the initial fuel components (calorific value, humidity, ash content and volatile of fuel mixtures under investigation) [29].

Fuel (wood/coal_grade), %	Q_n^r, MJ/kg	Technical characteristics, %			Elemental analysis, % *daf*			
		W^a	A^d	V^{daf}	C	H	N	$O+S_{opr}$
100 / 0	21,73	5,35	0,29	80,25	53,3	6,9	-	39,8
0 / 100_3B	25,79	5,41	3,45	40,09	71,23	6,12	1,95	20,70
10 / 90_3B	23,91	8,82	3,2	44,89	-	-	-	-
25 / 75_3B	23,83	14,21	3,11	47,41	-	-	-	-
50 / 50_3B	23,75	12,87	2,75	54,75	-	-	-	-

The data presented in Table 1 reflect the effect of wood on technical characteristics of fuel mixtures. It can be seen that with increase of wood concentration up to 50%, calorific value of the fuel decreases by less than 7.9% relative to the homogeneous coal of 3B grade. Analysis of the values of ash content of the studied fuels depending on wood concentration shows that increase of wood proportion to 50% leads to its decrease to 2.75% for composite fuel based on 3B coal (ash content of homogeneous 3B coal is 3.45%).

A comparison of theoretical and experimental values of ash content of the mixtures shows that their differences are significantly greater than systematic measurement errors and random error results. Changes of technical characteristics of the mixtures are not additive with respect to the ash content of the corresponding coals and wood.

2.2. Granulation of studied samples

Preparation of pellets of the studied mixed fuels was carried out by cold pressing by hydraulic manual press. The method of cold pressing eliminates energy costs of pre-drying the samples of fuel mixtures, their heating or additional sintering at relatively low temperatures. Samples of the mixed fuels were placed in a matrix with a through hole with a diameter of 8 mm with a stop cup fixed at the base. The pressing was carried out with a punch of the corresponding diameter, fixed on the hydraulic mechanism of the press, with a force of 2 tons of metric units. For the formation of fuel pellets of constant shape, a pressing matrix of a given configuration was used. The weight of the sample did not exceed 0.7 grams (the range of weight variation was no more than ± 0.01 grams).

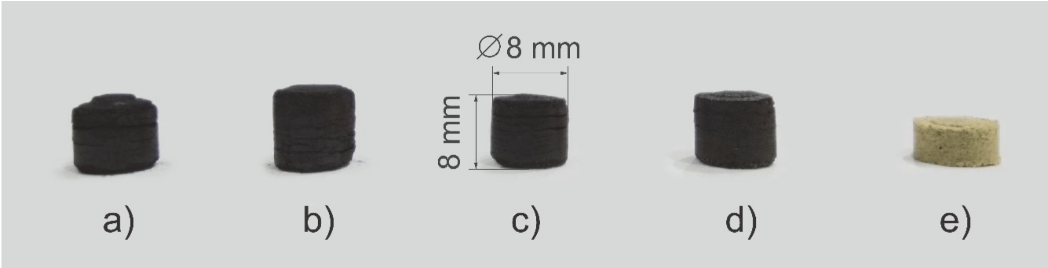

Figure 1. Schematic diagram of mixed fuel pellets preparation: a) lignite pellet, b) pellet with 10% sawdust, c) pellet with 25% sawdust, d) pellet with 50% sawdust, e) homogeneous sawdust pellet.

Sizes of the granules shown in Figure 1 correspond to a diameter of 8 mm and a height of 5 mm, the pellets were formed in a cylindrical shape (deviations of sizes from the average values did not exceed ± 0.5 mm).

2.3. Study of ignition and combustion processes

Experimental stand for determining ignition delay times of the studied pellets of mixed fuels and their initial components is presented in Fig. 2. The main elements of the stand are: high-speed video camera with an aspect ratio of 1024 × 1024 pixels, frame rate up to 100,000 per second; TSMP Ltd R14-U temperature-controlled oven with a digital temperature controller (measurement error ± 1 ° C); platform of the coordinate mechanism intended for entering the fuel pellet into the furnace with an error of movement in space less than 1 mm. The ignition delay time was considered the time from the moment the plate with the fuel pellet entered the camera focus until the beginning of the glow corresponding to combustion process. Registration of the process of thermal decomposition was carried out continuously until the sample was completely burned out. The errors of t_{ig} determination were: systematic less than 1%, random less than 2%.

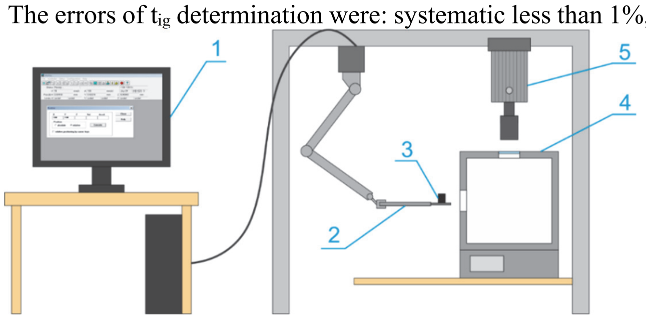

Figure 2 Schematic diagram of the experimental setup for determining the ignition delay times for mixed fuel pellets: 1 – Personal computer, 2 – Platform of the coordinate mechanism for the supply of fuel granules to the combustion chamber, 3 – Fuel pellets, 4 – Combustion chamber with adjustable temperature, 5 – High-speed video camera.

3. Results and discussion

Figure 3 shows the results of experimental determination of the ignition delay times t_z of mixed fuel powders based on components of 3B coal and sawdust.

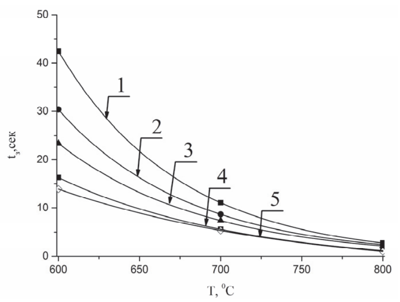

Figure 3. Dependence of the ignition delay time of composite fuels based on 3B coal on temperature at different concentrations of wood: 1 – homogeneous coal; 2 – mixture with a coal content of 90%; 3 – mixture with a coal content of 75%; 4 - mixture with a coal content of 50%; 5 – homogeneous sawdust pellet.

Analysis of Figure 3 allows estimating the effect of temperature on the ignition delay times of mixed fuel granules based on 3B coal and woody biomass. An increase of the temperature in the combustion chamber to 800°C leads to a decrease of the ignition delay time to 2.75s for homogeneous coal and to 1.12s for mixed fuel granule with components ratio of 50%/50%.

It should be noted that comparison of the experimental results with known values of ignition delay times for a single coal particle of small size and wood shows that at relatively low temperatures (600 <T <700 ° C), the values of t_z of mixture granules and individual components differ in 2.0 - 2.5 times (15-30 s). This is mainly due to the difference in the size of the granules and particles of coal and wood components. As the temperature rises to 800 ° C, the difference in t_z values decreases to 0.5-0.85 s.

Conclusion

The obtained results reflect the possibility of application of mixed fuel granules based on crushed coal and wood during fuel-bed combustion in the boiler units of coal-fired thermal power plants, as well as hot water boilers. Application of wood component in the mixed fuel significantly reduces the cost of pre-heating the furnace space with a slight decrease of energy characteristics of the used composite fuel granules with respect to homogeneous coal.

Acknowledgments

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References

[1] Coal Information: Overview (2017 edition) / Energy Efficiency Indicators Highlights
[2] Friedland V S, Livshits I M *Thermal power* 2011 **1** 72–77
[3] Supranov V M, Izyumov M A, Roslyakov P V 2011 *Thermal Power Engineering* **1** 44–54
[4] Chen L, Li X, Han L 2009 *Renew Sust Energy Rev* 13:2689–95
[5] Baliban R C, Elia J A, Christodoulos A F 2010 *Ind Eng Chem Res* 49:7343–70.
[6] Yezhova N N, Vlasov A S, Delitsyn L M 2006 *Ecology of industrial production* **2** 50–57
[7] Fedyukhin A V 2014 *Development of combined heat and power generation based on the study of the pyrolysis and gasification of biomass* Dis. ... Cand. tech. Sciences p 157
[8] Pavlov, D.A. 2014 *Modern high technologies* **5** (1) 181
[9] Sanaev Yu I 1948 *Survey information* Series XM-14 (M., "TSINTIHIMNEFTEMASH")
[10] Vershinina K Yu 2017 *HTT* **2** 30
[11] Nyashina G S, Schlegel N S, Strizhak P A 2017 *Cox and Chemistry: Scientific, Technical and Production Journal* **4** 40
[12] Kovenskiy V I 2012 *Teploenergetika* **8** 34–8
[13] Muthuraman M, Namioka T, Yoshikawa K 2010 *Fuel Processing Technology* **91** 550
[14] Al-Mansour F, Zuwala J 2010 *Biomass and Bioenergy* **34** 620–9
[15] *Growing Power – Advanced solutions for bioenergy technology from Finland* 2002 (Tekes & VTT Processes & Teonsana Oy. Lahti) p 34
[16] *TUBITAK. Coal-Biomass Mixed Combustion Technology Call for proposal* 2016:3 http://www.tubitak.gov.tr
[17] Wannapeera J, Fungtammasan B, Worasuwannarak N 2011 *J Anal Appl Pyrol* **92** 99–105
[18] Sonobe T, Worasuwannarak N, Pipatmanomai S 2008 *Fuel Process Technology* **89** 1371–8
[19] Kuznetsov G.V., Yankovskii S.A. 2019 *Thermal Engineering* **66** (2) 133–7
[20] Xiang-guo L, Bao-guo M, Li X, Zhen-wu H, Xin-gang W 2006 *Thermochimica Acta* **441** 79
[21] Haykiri-Acma H, Yaman S, Kucukbayrak S. 2013 *Appl Therm Eng* **50** 251–9
[22] Wang J, Li Y 2011 *Bull Chin Acad Sci* **25** 56–8
[23] Plis A, Kotyczka-Morańska M, Kopczyński M, Łabojko G 2016 *Journal of Thermal Analysis and Calorimetry September* **125** (3) 1357–71
[24] Ushakov A G, Ushakova E S, Ushakov G V 2014 *St.Peterssrurg State Politechnical Universiti Journal* **3** (202) 70−9
[25] David N, John Z *Gen. Tech. Rep. PNW-GTR-867* (Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station) p 22
[26] Van der Stelt MJC, Gerhauser H, Kiel JHA, Ptasinski KJ 2011 *Biomass Bioenergy* **35** 3748–62
[27] Nunes LJR, Matias JCO, Catalo JPS 2014 *Renew Sustain Energy Rev.* **40** 153–60
[28] Kuznetsov G V, Jankovsky S A, Tolokolnikov A A & Zenkov A V 2018 *Combustion Science and Technology* 1–12