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Reasons for tangerine peel utilization in the composition of mixed fuels based on bituminous coal

Reasons for tangerine peel utilization in the composition of mixed fuels based on bituminous coal

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Abstract. Application analysis of processed tangerine peel in a mixture with T grade coal (lean) as a fuel for hot water boilers is presented. Technical characteristics, as well as conditions and ignition delay times for such mixed fuels at different mass concentrations of the initial components, have been experimentally determined. The experiments were carried out in air at temperatures from 600 ° C to 800 ° C. Record of ignition and combustion processes of composite fuel samples was carried out using a high-speed video camera (image format — 1024 × 1024 pixels, frame rate — up to 1000000 per second), which ensures high discretization of the recording results of characteristic process times. A temperature limit has been identified for the stable ignition of such fuels. It has been established that an increase of tangerine peel proportion in the mixture leads to acceleration of ignition processes of the studied mixed fuels. Reasons for application of fuel mixtures based on bituminous coal and food waste in the small energy sector have been provided.

1. Introduction

Production of electricity and heat from combustion of coal in the furnaces of hot water boilers is also relevant in the XXI 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.

Technology of pelletizing composite fuels is of greatest interest for practical use, which is based on two basic components: coal and biomass, without application of expensive binding additives and the cost of additional steam production necessary for sintering such fuels [24]. The technology of cold pressing [25] involves application of coal dust and crushed tangerine peel in a state of homogeneous mixture, followed by formation of adhesive forces under mechanical pressure into a dense granule [26].

The main problem, the solution of which is necessary for development of pellet burning technologies, is that, as established by the results of studies [27], delay times of ignition of droplets and particles of any fuels (liquid [28], solid [29], slurry [30]) substantially depend on the size of the particles (or droplets). The larger these characteristic dimensions, the longer the ignition delay time, respectively. In this case, there are certain problems for implementation of the processes of pellets manufacture and their combustion. The larger the pellets, the lower the cost of their manufacture, but there are serious time intervals for their ignition when burning large pellets. In this regard, one of the main tasks in the development of technologies for manufacture and combustion of pellets is to establish links between ignition conditions and particle sizes at certain acceptable temperatures of the oxidizing environment (air).

2. Experimental section

2.1. Experimental section

T grade (“Alardinskoe” deposit) was used in the experimental studies with particle size less than 80 microns. The second component was the food waste "Tangerine peel" (particle size was less than 200 microns).

Fuel mixtures were prepared from particles of coal and tangerine peel and were 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 [31]. 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 [31]. 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 [32] and are listed in Table 1.

Table 1. Elemental composition and technical characteristics of the initial fuel components (heat of combustion, humidity, ash, volatiles) of the studied mixtures.

Fuel (tangerine peel / coal_grade), %	Technical characteristics				
	A^d,%	W^a,%	V^{daf},%	Q_n^r, MJ/kg	R_{80}
100 / 0	1,89	5,61	80,41	16,79	87,14
0 / 100_T	18,37	5,61	24,93	25,72	1,67
10 / 90_T	15,23	5,61	29,49	23,32	11,46
25 / 75_T	13,38	5,61	38,99	22,17	12,34
50 / 50_T	9,10	5,61	55,22	20,20	34,6

Analysis of the experimental results presented in Table 1 allows establishing the synergistic (non-additive) effect of ash content decrease and increase of yield of volatile substances of the studied mixtures depending on concentration of the biomass component. These are the main characteristics for fuel combustion in the furnaces of power boilers. For composite fuels based on T grade coal, an increase of the peel proportion to 50% leads to a decrease of ash content from 18.37% to 9.10%. Yield of volatile substances increases from 24.93% (homogeneous T grade coal) to 55.22%.

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).

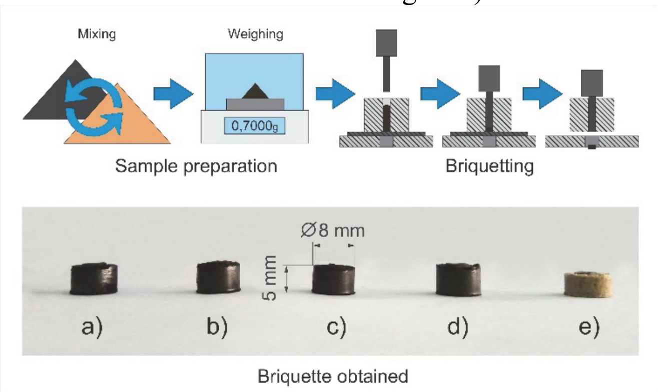

Figure 1. Schematic diagram of mixed fuel pellets preparation:
a) homogeneous coal pellet, b) pellet with 10% peel content, c) pellet with 25% peel content, d) pellet with 50% peel content, e) homogeneous peel pellet.

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 ovement in space less than 1 mm. The ignition delay time was considered 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%.

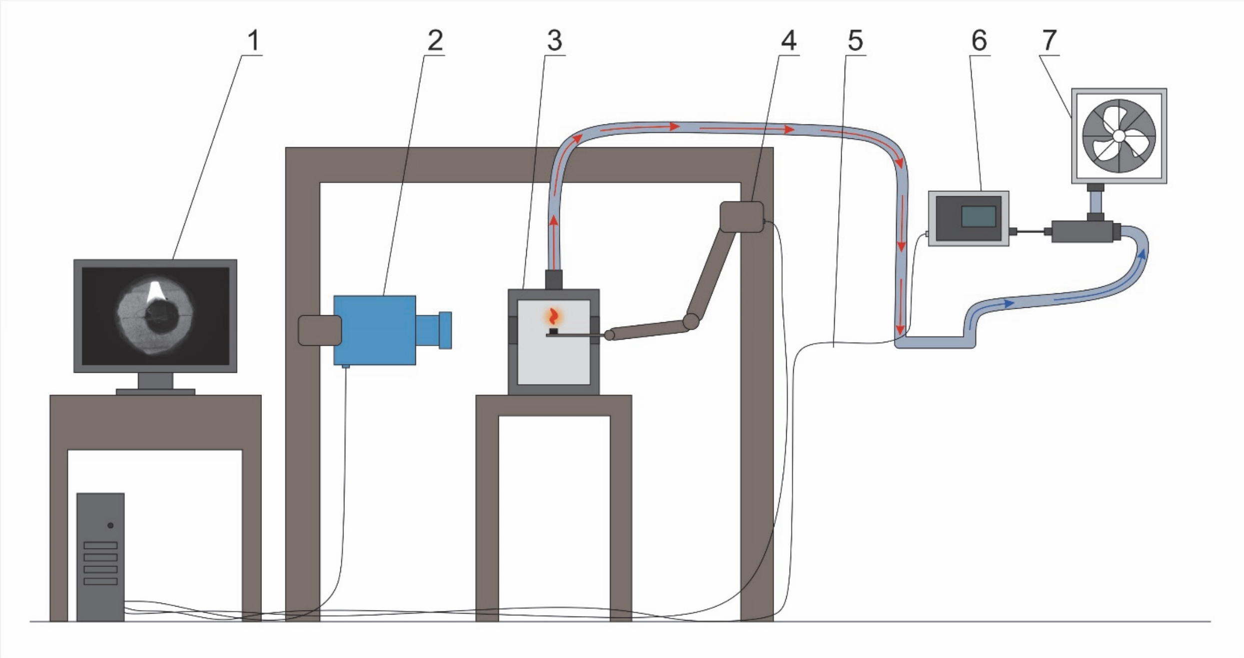

Figure 2. Schematic diagram of the experimental setup for determining the ignition delay times for mixed fuel pellets: 1 – personal computer, 2 – high-speed video camera, 3 – combustion chamber with adjustable temperature, 4 – coordinate mechanism platform for supplying fuel pellets to the combustion chamber, 5 – connection to PC, 6 – portable gas analyzer, 7 – ventilation system.

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 the T grade coal and tangerine peel.

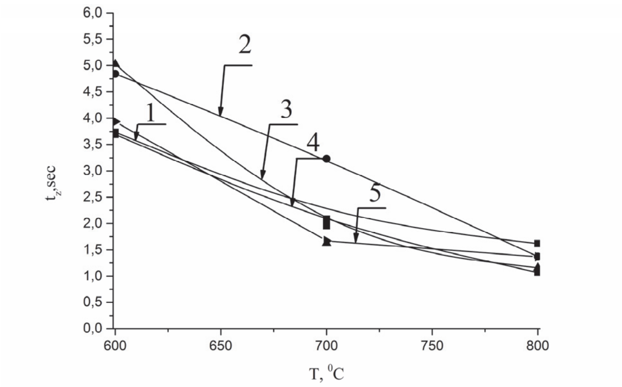

Figure 3. Dependence of the ignition delay time of composite fuels based on T grade coal on temperature at different concentrations of tangerine peel: 1 – coal; 2 – mixture with a coal content of 90%; 3 – mixture with a coal content of 75%; 4 – mixture with a coal content of 50%; 5 – tangerine peel

It can be seen from Figure 3 that with temperature increase from 600°C to 800°C for homogeneous T grade coal the ignition delay time decreases by a factor of 2.3, and for tangerine peel it decreases in 2.9 times. With an increase of the tangerine component to 50%, the ignition delay time of mixed fuel decreased in 3.4 times at temperature growth from 600°C to 800°C.

Figure 4 shows the results of experimental determination of the ignition delay times t_z of mixed fuel pellets based on T grade coal and tangerine peel components.

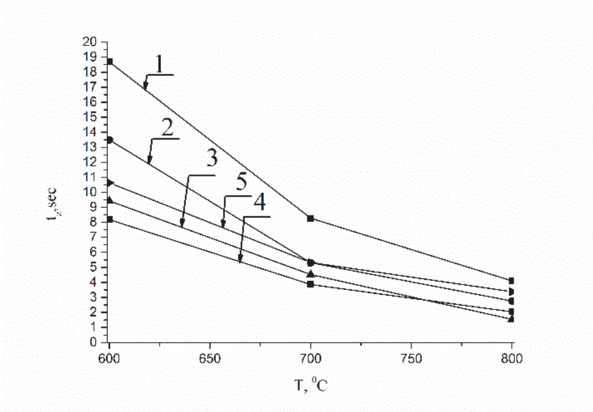

Figure 4. Dependence of the ignition delay time of mixed fuel pellets based on T grade coal on the temperature at different concentrations of tangerine peel: 1 – coal; 2 – mixture with a coal content of 90%; 3 – mixture with a coal content of 75%; 4 – mixture with a coal content of 50%; 5 – tangerine peel.

Analysis of Figure 4 allows estimating the effect of temperature on the ignition delay times of composite fuel pellets based on T grade coal and tangerine peel. Increase of the temperature in the combustion chamber to 800 ° C leads to a decrease of the ignition delay time to 4.1 s for homogeneous coal and to 2.04 s for mixed fuel pellets with a ratio of 50% / 50%. Increase of the rate of thermal decomposition of such mixed fuel pellets is due to the high reactivity of T grade coal and tangerine peel.

Conclusion

The results of experimental studies allow substantiating the possibility of using tangerine peel together with crushed coal in the form of solid pellets with characteristic sizes up to 8 mm in the small energy industry. Adding waste of tangerine peel to coal dust with subsequent formation of mixed fuel pellets significantly reduces the ignition delay time compared to a homogeneous coal granule. The limiting (according to the temperature of the flue environment) conditions for stable ignition and combustion of mixed fuel pellets were established.

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