Thermal decomposition of thermally treated granulated wood

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Abstract* – *The derivatographic method was used to study the thermal decomposition of pine wood, which was thermally treated in the form of granules at atmospheric pressure under its own gas environment. It is shown that an increase in the treatment temperature from 250 to 300 °C leads to the temperature range extension of decomposition of the fuel and an increase in its calorific value.

Keywords – derivatography, wood, torrefaction, thermal treatment, thermal decomposition, temperature and heat of thermal decomposition

Introduction

Plant biomass is an important source of renewable raw materials and energy. However, low energy density, instability of granulometric composition and physical properties, and also biological activity and dispersion over the territory are the main problems in its energy and technological use [1]. It is necessary to improve fuel properties of biomass for more efficient its using as an energy source. One of the ways of such an improvement is granulation, which allows to increase the specific heat of combustion, and also to improve transportable characteristics. A promising step is torrefaction of biomass in increasing the energy density and efficiency of biofuels using. Torrefaction is a mild pyrolysis process in an inert atmosphere, in the temperature range of 200–300 °C. The thermal destruction observed in this process is accompanied by a change in the mass and composition of the biomass. As a result, the percentage of oxygen decreases and the content of hydrogen and carbon increases, which leads to an increase in heat of combustion [2]. Torrefaction allows to maximally approximate the properties of biofuels to the properties of energy coals. The yield and calorific value of the finished product depends on the depth of thermal treatment. Therefore, when studying the torrefaction process, developers try to find the optimal mode that allows one to achieve the highest calorific value with the least loss of the initial energy. Various types of biomass can be subjected to torrefaction, including agricultural waste and "energy crops" that have fairly similar physical and chemical properties [3].

Materials and methods

Granules of pine wood with a diameter of 8 mm and a length of 30–40 mm was charged into the steel non-hermetic containers and subjected to thermal treatment in a muffle furnace in their own gas medium at atmospheric pressure. The temperature of the material during thermal treatment process was measured with a thermocouple passing through a hole in the lid of the container. Upon reaching the muffle furnace temperatures of 250, 260, 270 and 290 °C, a container with granules was placed in the furnace. The warm-up time of the material to the set temperature was 30 minutes. After warming-up thermal treatment process was continued for 60 minutes. The destruction of wood is an exothermic process and therefore the temperature of the material has increased. By the end of thermal treatment, the material temperature exceeded the base temperatures of the muffle furnace by 15 K at 250, 260 and 270 °C and by 10 K at 290 °C. At the expiration of thermal treatment time, the containers were removed from the muffle furnace and cooled to room temperature.

The obtained fuel samples were subjected to thermal analysis in the range of 20–1000 °C with a temperature scanning rate of 7.4 K/min on the derivatograph Q-1000, modernized at the

IET of NAS of Ukraine. Before the study, the fuel samples were ground in a porcelain mortar and placed in a conical ceramic crucible from the instrument kit. In the crucible of comparison was an inert substance – Al_2O_3. The temperature scale was corrected using the transition temperature of quartz from α- to β-form (573 °C). The temperature deviation did not exceed ±0.5 K. The collection and processing of information from the channels of measurement was performed using the applied computer program "Derivatograph".

Results

A derivatogram of a sample of fuel obtained after thermal treatment of wood granules at 270 °C is shown in Fig. 1 as an example. To compare the results of thermal treatment, the wood of the initial granules was subjected to thermal analysis. As can be seen from the curves of change in mass velocity (DTG) and differential thermal analysis (DTA), bound water is removed in the initial heating period (up to 150–190 °C).

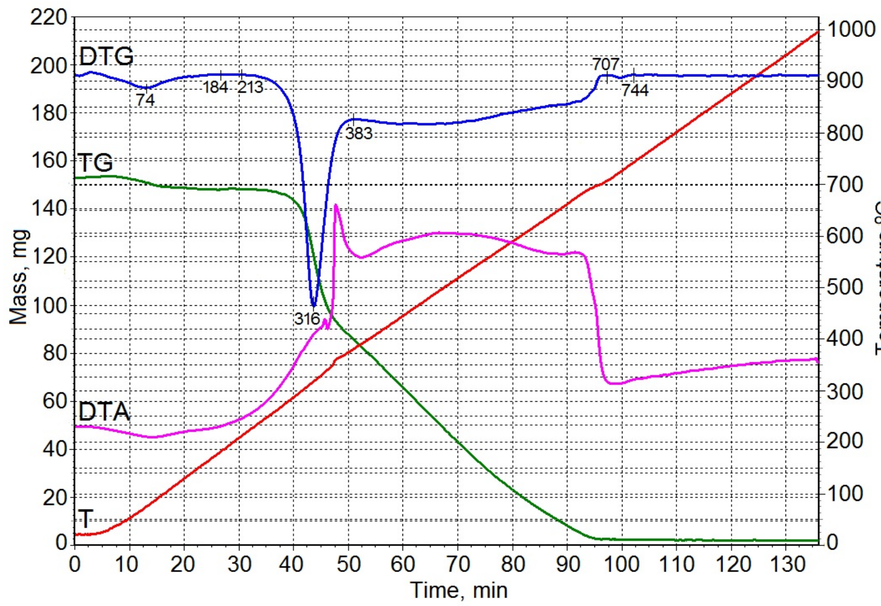

Fig.1. Derivatogram of fuel obtained after thermal treatment of pine wood granules at 270 ºC.

The components of wood decompose in different temperature ranges, which cause the multistage nature of its destruction. Thermal decomposition of hemicelluloses occurs in the temperature range of 225–325 °C, cellulose decomposes in the range of 305–375 °C, and lignin is characterized by a gradual decomposition from 250 to 500 °C [1].

An analysis of the DTG curves showed that the proportion of the mass of the sample of untreated wood, which thermally decomposing in the temperature range from complete dehydration to 325 °C, is 36.8 %. When the temperature of thermal treatment is increased, this proportion decreases from 27–28 % at 250–260 °C to 11.4% at 290 °C. This indicates a decrease in the content of hemicellulose in the composition of the resulting fuel.

Thermal treatment of wood expands the temperature range of thermal destruction, which follows from the DTA curves shown in Fig. 2. For wood treated at 250 °C, thermal decomposition is observed in the range from 203 to 727 °C. While for untreated wood, destruction starts at 170 °C and ends at 606 °C. An increase in thermal treatment temperature leads to a shift in the temperature of the end of thermal decomposition to higher temperatures (up to 788 °C for the treated at 290 °C).

Evaluation of the heat of thermal decomposition showed that the mild thermal treatment of pine wood leads to an increase in the specific heat of thermal decomposition. The increment of specific heat in comparison with the specific heat of untreated wood increases with increasing thermal treatment temperature by 18–20 % at 250–260 °C and 27 and 39 % at 270 and 290 °C, respectively.

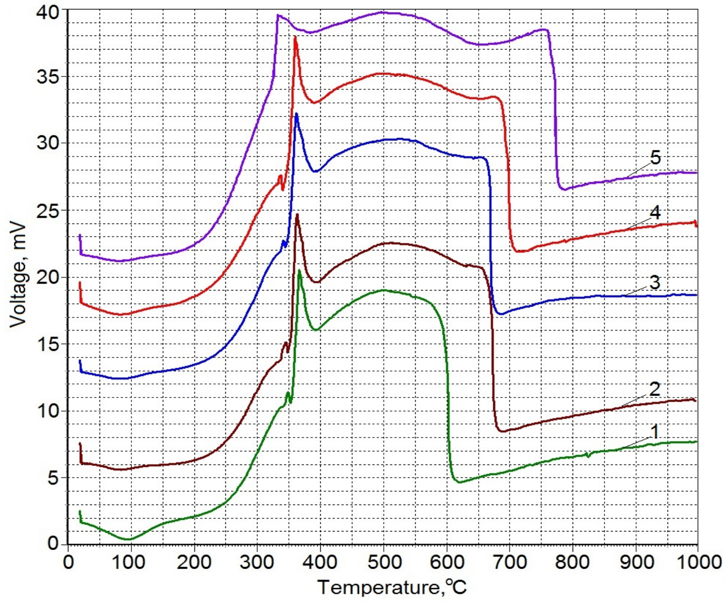

Fig.2. DTA curves of pine wood granules before (1) and after thermal treatment at 250 (2), 260 (3), 270 (4) and 290 °C (5).

Thus, the calorific value of pine wood can be increased from 15.5 to 21.5 MJ/kg due to thermal treatment. The ash content of thermally treated wood is slightly higher than the initial (before treatment – 0.76 %, after treatment at 290 °C – 1.84 %). Thermal effect on wood causes a reduction in the number of hydrophilic active centers, which leads to an increase in the hydrophobicity of the fuel, and, consequently, to a decrease in its equilibrium moisture. The moisture of the granules after thermal treatment and storage was in the range of 2.65–3.74 %, while the moisture of the untreated granules stored under the same conditions was 7.33 %.

Conclusion

Thermal analysis of torefied pine wood granules showed that the degree of its decomposition depends on the temperature and time of thermal treatment. Torrefaction is an effective way to improve the energy characteristics of biofuels.

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