Study of effect of thermal activation of coal-water fuel on processes of its ignition and burning

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Abstract
The experimental and theoretical studies of laws of physical and chemical transformations in the course of thermal activation of coal-water fuel are conducted. It is established that preliminary thermal activation of coal-water fuel at temperatures of 150... 200 °C leads to change of properties and structure of fuel with formation of intermediate fuel compounds. Regularities of thermal activation impact on temperature and time characteristics of processes of ignition and burning of coal-water fuel and combustion degree of combustible mass of fuel are determined experimentally. It is shown that application of preliminary thermal activation of coal-water fuel is conductive to stable ignition and steady burning and leads to increase of burning efficiency.
Key words: COAL-WATER FUEL, COAL, THERMAL ACTIVATION, PHYSICAL AND CHEMICAL TRANSFORMATIONS, METAMORPHISM STAGE, GAS-VAPOR PHASE, IGNITION, TEMPERATURE AND TIME CHARACTERISTICS, DEGREE OF COMBUSTION

At the present time, share of coal is 29% in structure of fuel and energy balance of the world [1]. The considerable part of the extracted coal is characterized by the increased content of mineral impurity and sulfur that requires application of different methods of coal beneficiation and, respectively, leads to considerable accumulation of waste of coal beneficiation. One of the promising directions of power engineering is use of coal-water fuel in different power stations of the coal-water fuel (CWF) obtained from low-grade coal, water-cut coal fines, wet slimes and waste of concentration plants, which are not in use now, that can provide considerable economic and ecological effect [2-4]. As in case of preparation of coal-water fuel, the use of different grades of coal and waste of coal preparation, properties of obtained fuels, and, therefore, mechanisms of physical and chemical transformations and kinetics of chemical reactions at thermal and thermochemical effect are quite different [5, 6].

Moreover, in case of combustion of coal-water fuel made of high-ash low-volatile coal, unstable igni-

tion and burning of fuel in fire chambers of the existing power stations are observed that results in low energy efficiency of its burning. One of the directions of these problems solution is preliminary thermal activation of fuel. Consequently, research of laws of physical and chemical transformations in the course of thermal activation of coal-water fuel from coals of different stage of metamorphism will allow setting rational parameters of activation which leads to desirable and controlled changes of properties and structures of fuel, and finally, to increase in energy efficiency of fuel combustion. Important indices of thermal activation are temperature at the beginning of formation of steam-gas phase and area of its maximum formation, speed of formation, quantity and composition of steam-gas phase depending on the initial characteristics of fuel and key parameters of impact (temperature, pressure, time). The experimental and theoretical studies of thermal activation of coal-water fuel were conducted for fuels with so- lid phase 50 … 70% and mineral impurity – 0.5 … 60%. The technology of coal-water fuel preparation consisted of stages of wet grinding in a ball mill and cavitational treatment; at the same time, the maximum possible content of solid phase, the minimum viscosity and necessary sedimentation stability were provided. The size of carbon particles in all the samples of coal-water fuel was less than 250 microns. Sodium lignosulfonate was used as plasticizing agent in amounts of 1%. Results of the experimental thermogravimetric researches of influence of temperature and time of thermal activation in case of atmospheric pressure on dynamics of steam-gas phase formation from the coal-water fuel obtained from coals of different grades are provided in Figure 1.

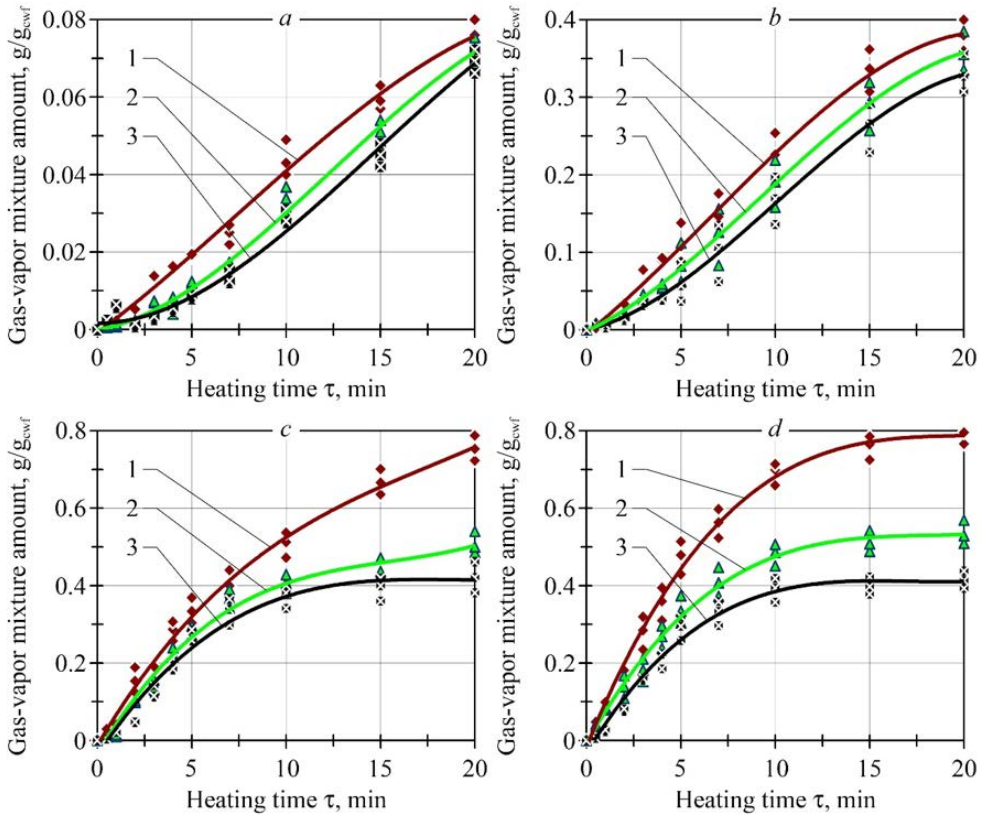

Figure 1. Dynamics of formation of a steam-gas phase in case of thermal impact on the coal-water fuel obtained from coal of different grades at temperatures 50 °C (a), 100 °C (b), 150 °C (c) and 200 °C (d): 1 - coal-water fuel from brown coal; 2 - coal-water fuel from long-flame coal; 3 - coal-water fuel from anthracite

The analysis of obtained results shows that the speed of formation and quantity of steam-gas phase is the greatest for the coal-water fuel made of brown coal which belongs to low stage of metamorphism. Whereas, for the coal-water fuel obtained from anthracite, the speed of formation and quantity of steam-gas phase are the lowest. In case of thermal activation of coal-water fuel at temperatures of 50... 100 °C, continuous increase in quantity of steam-gas phase for all the samples of coal-water fuel is observed; and in case of temperature increase to 150... 200 °C, more intensive output of a steam-gas phase is observed at the same timeframe and dependence of physical and chemical transformations on characteristics of the initial coal is more considerably shown in the course of thermal activation. In case of thermal activation of

more than 15 min., the quantity of steam-gas components does not almost changed for all the samples of coal-water fuel. However, it does not mean absence of chemical reactions, and assumes intermediate chemical components formation, which is carried out without gas generation. For samples of coal-water fuel obtained from other grades of coal, laws of physical and chemical transformations in the course of thermal activation are similar to given above.

As researches [7] have shown, chemical interaction of water with carbon already begins at temperatures of 30... 40 °C that is caused by coal mechanical treatment which is one of stages of coal-water fuel preparation. Mechanical activation of coal is followed by emissions of volatile organic and soluble low-molecular products which are result of mechanic and chemical transformations of organic substances of coals [8]. With temperature increase of more than 50 °C, the speed of reaction of carbon with water (water vapor) considerably increases. These interaction proceeds through the vapor adsorption on carbon surface with formation and separation of H_2, CO, CO_2, C_xH_y in the gas phase.

The ratio of steam-gas and solid phase in case of thermal activation of coal-water fuel of coal of different grades is 39 ... 79% and 21 ... 61% depending on characteristics of the initial raw materials and parameters of activation. However, despite different quantity of the formed steam-gas phase, the ratio of steam and gas components in a steam-gas phase is almost identical to all the samples of coal-water fuel. In case of heating of coal-water fuel to 50 °C, the content of vapour in a steam-gas phase of different grades of coals is 12... 14%, and gas components – 86... 88%. The further heating of samples of fuel to 100 °C leads to the substantial increase of a steam phase to 66... 68%, and at temperature of heating of fuels to 150... 200 °C, the amount of vapor in a steam-gas phase is reduced to 56... 61% that can be explained by interaction of fuel carbon vapor with the subsequent formation of combustible components and intermediate radicals. At the same time, the content of gas components in a steam-gas phase of coal-water fuel of different grades of coal is 38 ... 44%.

It is recommended to perform preliminary thermal activation of coal-water fuel with pressure of 0.5... 1.5 MPa inasmuch as thermal activation in case of atmospheric pressure proceeds with the considerable evaporation at temperatures 80...100 °C that causes deterioration in rheological properties [9]. The conducted researches have shown that with pressure of 0.5... 1.5 MPa, dynamics of formation and composition of steam-gas phase in case of thermal activation of coal-water fuel are similar to the processes mentioned above, but at the same time, the shift of activity of steam-gas phase output to the area of more high temperatures takes place that is due to increase in saturation temperature in case of more high pressures.

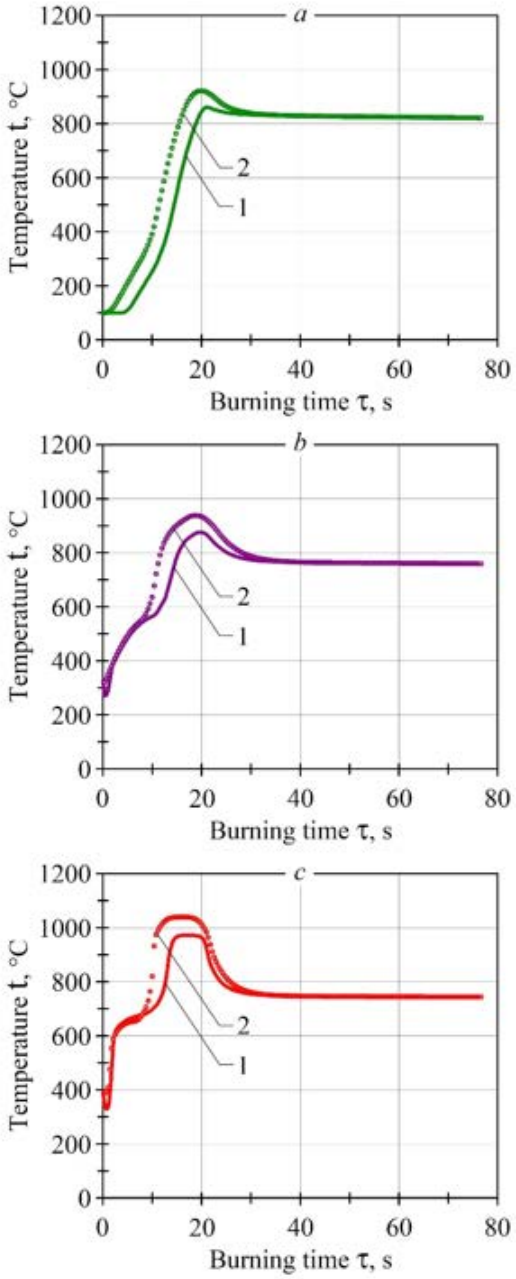

Figure 2. The experimental values of temperature of coal-water fuel made of brown coal (a), medium temperature at distance of 2 mm (b) and 5 mm (c) from coal-water fuel made of brown coal: 1 - without thermal activation, 2 - after thermal activation

Researches have shown that preliminary thermal activation of coal-water fuel at temperatures of 150... 200 °C leads to improving of its rheological properties, change of structure of organic substance of fuel with formation of the intermediate fuel compounds. Moreover, the fuel cooled after thermal acti-

vation keeps its features that makes possible to draw a conclusion that in case of activation irreversible changes in fuel composition take place.

For an impact evaluation of preliminary thermal activation on laws of burning of coal-water fuel from coals of different stage of metamorphism, the experiment studies of activation impact on temperature and time characteristics of ignition and burning of fuel are conducted.

Dependences of temperature change of coal-water fuel made of brown coal and temperatures of medium around fuel drops of 5 mm in size without thermal activation and after preliminary thermal activation on time of burning τ of a sample of coal-water fuel at a temperature of work space of the furnace of 700 ° C are presented in Figure 2. As is seen from obtained data, burning of water carbon fuel after preliminary thermal activation has distinctive features in comparison with burning of fuel without thermal activation [10].

As it was earlier discussed in this paper, in case of preliminary thermal activation of coal-water fuel, reaction activity of fuel increases and considerable amount of gaseous components are formed; therefore, when burning of activated fuel separation and interaction of gaseous products is more intensive, and ignition of volatile substances takes place by 14 … 16% earlier in comparison with not activated coal-water fuel. Medium temperature around fuel sample when burning volatile substances increase by 6 … 8%, and duration of volatile substances burning increases by 23 … 25%. At the same time, carbon resi- dual is inflamed faster, time necessary for its complete burning is reduced by 8 … 10%, and the level of burning increases by 5 … 8%.

Moreover, preliminary thermal activation of water carbon fuel will allow reduction of energy consumption for water phase evaporation directly in furnace space of the power generating unit that will allow stabilizing the process of burning and temperature level in a fire chamber. Results of the experimental researches of thermal activation impact on laws of inflaming and burning of coal-water fuel obtained from other grades of coals are similar to given above.

In Figure 3, change of temperature of coal-water fuel drop made of brown, long-flame coal and anthracite of 1 mm in size without thermal activation and after activation in case of its burning in an air medium is provided. Dependences are given at different temperatures of work space of the furnace. From the obtained data, it is seen that in the researched interval of temperatures in the samples of coal-water fuel, which passed thermal activation, time before inflaming is less by 15 … 17% on average, time of complete burning is 10% less, and the maximum temperature of the burning drop is higher by 7 … 8%, in comparison with fuel, which did not undergoes thermal activation.

Thus, interrelation between thermal activation of coal-water fuel and indices of process of its inflaming and burning is established. The obtained data can be used for development of highly effective technologies of thermal processing of coal-water fuel and improvement of technologies of its production.

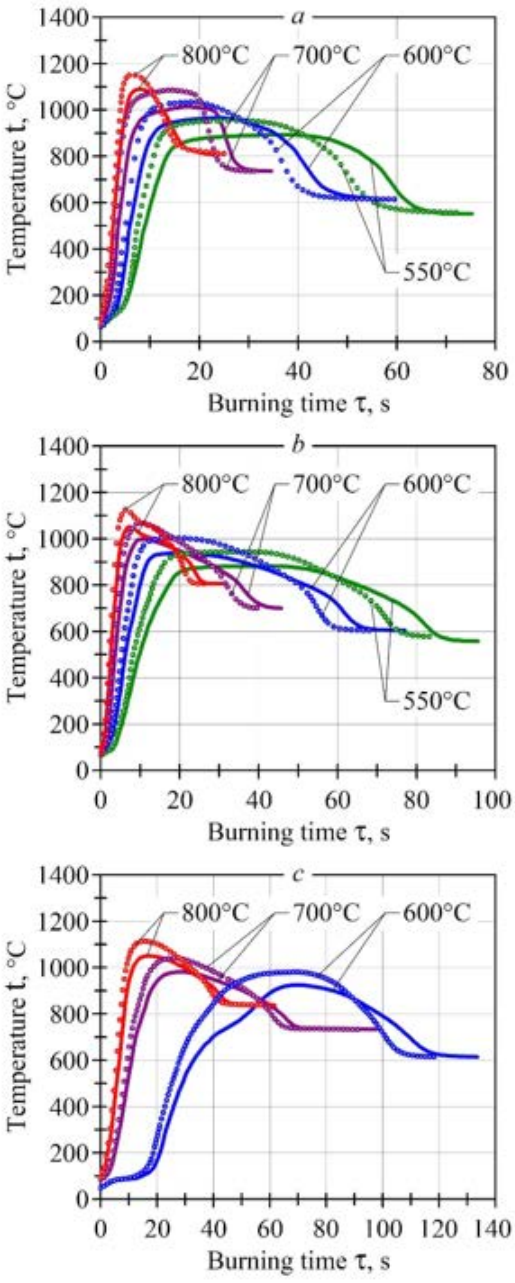

Figure 3. Temperature and time characteristics of coal-water fuel drop made of brown coal (a), long-flame coal (b) and anthracite (c) in case of its burning in air medium: – fuel sample without thermal activation; – fuel sample after thermal activation

Conclusions

The experimental and theoretical studies of influence of thermal activation in the temperature range 50... 200 ° C during 1... 20 minutes of physical and chemical transformations in coal-water fuel have shown that in case of such activation the steam-gas phase is formed in amount of 40... 80 % depending on characteristics of fuel and parameters of activation. At the same time, the content of gas components (H_2, CO, CO_2, C_xH_y) in a steam-gas phase is 38... 44 % of total amount.

It was found out that preliminary thermal activation of coal-water fuel at temperatures of 150... 200 °C leads to improving of its rheological properties and change of structure of organic substance of fuel with formation of the intermediate fuel compounds. Moreover, the fuel cooled after thermal activation keeps its features that makes possible to draw a conclusion that in case of activation irreversible changes in fuel composition take place.

The experimental researches have established that in the considered range of temperatures in case of thermal activation of fuel inflaming of volatile substances takes place by 15... 17% earlier, duration of burning of volatile substances increases by 23... 25%, and maximum temperature of burning drop is higher by 7... 8 in comparison with non-activated coal-water fuel under similar conditions of burning. At the same time, carbon residual is inflamed faster, time necessary for its complete burning is reduced by 8 … 10%, and the level of burning increases by 5 … 8%. Moreover, preliminary thermal activation of water carbon fuel will allow reduction of energy consumption for water phase evaporation directly in furnace space of the power generating unit that will allow stabilizing the process of burning and temperature level in a fire chamber.

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