THERMAL CONVERSION OF THE PEAT TO COMBUSTIBLE GASES

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Abstract. Presented thermal characteristics of the peat and semi-coke derived on its basis. Presented the results of studies of the pyrolysis and catalytic conversion of peat and semi-coke at temperatures of 300-450 °C. According to the results of experiments to determine the composition and calorific value of combustible gases, obtained as the result of peat thermal conversion and semi-coke based on it. Presented the structure and analyzed the material balance and the energy distribution of derived products by the thermal conversion.

1 Introduction

Perspective directions of the Power Engineering development of Russia cause the relevance of centralized power system combinations with off-grid power plants using low-grade raw materials as a fuel.

Scientific direction of the research is to develop an approach to the deep conversion of fuels organic matter into combustible gases at low temperatures (maximum 500 °C). Advantages of this approach: low process temperatures that allows to refuse expensive constructive materials; minimum ballast in gas; the possibility to generate hydrogen-rich gas; the possibility of organizing process in autothermal mode. [1]. Obviously, that it is extremely difficult to carry out a deep conversion of carbon fuels into combustible gas at the low-temperature heating of solid organic material that is the main problem of research. Thus, disadvantages of the process is reduced intensity, additional energy costs of preparing the steam [1]. The solution of this problem will allow us to develop a new direction in the study and creation of technique and technology of resource-efficient production of fuels and energy.

The object of study is the process of low-temperature conversion of low-grade fuels, characterized by the following provisions: converting organic matter into combustible fuel gases flows under the influence of temperature in the range of 300-450 °C at atmospheric pressure and without supplying oxygen blast; into active reaction zone entered the catalytic

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additive and steam with temperature corresponding to the level of the conversion process
(300-450 °C) ; achieved maximum level of organic matter fuels conversion to hydrogen-
rich combustible gas with the minimum ballast share [2].

2 The features of studying samples

The features of peat sample and the semi-coke obtained on its basis are given
in the Table 1.

Table 1. The features of studied samples (IS – initial sample, SC – semi-coke from the initial
sample).

Calculated mass Features	Operating mass		Dry mass		Dry & ashless mass	
	IS	SC	IS	SC	IS	SC
VOC, %	–	–	–	–	75.40	7.08
Moisture, %	69.90	0.66	–	–	–	–
Ash levlel, %	4.49	24.20	14.92	24.36	–	–
Carbon, %	12.50	73.06	41.53	73.54	48.81	97.24
Hydrogen, %	4.11	0.98	13.65	0.99	16.05	1.30
Oxygen, %	8.50	1.00	28.24	1.01	33.19	1.33
Sulfur + Nitrogen, %	0.50	0.10	1.66	0.10	1.56	0.13
The net calorific value, MJ / kg	7.5	25.40	24.92	25.57	29.29	33.80

The peat has a high moisture content (69.9 %) at low ash level value (4.49 %) in the
operating mass, that considerably determines the slight calorific value equal 7.5 MJ/kg. The
emission of volatile organic compounds (VOC) is characterized by a high value (75.4 %) to
fuel of the early stages of metamorphism that the indicating about high reactivity of peat
capacity provided to reduce its moisture content.

Ash level of the dry mass is 14.92 %, that slightly higher than milled peat (Rostorf). In
dry state, the peat has a quite high calorific value (24.92 MJ / kg) due to the high carbon
(41.5 %) and hydrogen (13.7 %) content. High oxygen content is negatively affects on the
calorific value of dry mass, however, this amount of oxygen is inherent in "young" coals.
At the same time, high oxygen content in the fuel leads to the conclusion that during the
thermal conversion of fuels will be observed exothermic heat effect, which will allow,
either reduce the amount of heat depending on the process temperature, involved into the
process, or to arrange it in autothermal mode [3, 4].

Semi-coke derived from the peat has a low VOC value (7.1 %) and almost no moisture
(0.7 %), compared with the initial state of peat. In this case, the ash level has a quite high
value (24.2 %). The organic part consists mainly of carbon (97.2 %) with low hydrogen
(1.3%), oxygen (1.3 %) and nitrogen (0.1 %) content in fuel. Due to the small value of
VOC and huge carbon content, it is difficult to organize the burning of peat's semi-coke.
However, it has been known that obtaining heat from the semi-coke can be performed in a
glow mode. At the same time due to the small content of VOC, the combustion gases are
colorless, and the intensity of the process is maintained by highly porous fibrous structure
of the semi-coke, which ensures the supply of atmospheric oxygen to the required extent.

Despite close to the limit of carbon content in the organic part of peat's semi-coke the net calorific value of operating mass is 25.4 MJ/kg (with the calorific value of 33.8 MJ/kg of a dry ashless mass), due to the high ash content. In general, we can say that the peat's semi-coke is a promising energy feedstock.

3 The features of obtained gases

According to the results of experiments to determine the composition and calorific value of combustible gases, obtained as the result of peat thermal conversion and semi-coke based on it (Fig. 1).

By increasing the temperature of treatment increases the content of hydrocarbon gases, first due to the increase of hydrogen and methane. The concentration of carbon monoxide, conversely, is reduced, which is caused by reactions in the early stages of the heat treatment. High oxygen content in the gas ballast caused by high surface area of the initial fuel with a large amount of adsorbed air.

According to the composition of combustible gases defined their net calorific value. Obviously, that the calorific value of the gases is determined primarily by the amount of methane. The increasing of gas calorific value from the peat throughout the entire studied temperature range provided an increase in the content of the gas methane and hydrogen with a slight fall of carbon monoxide. During the catalytic process, there is a noticeable increase in the concentration of combustible components first of all – hydrogen.
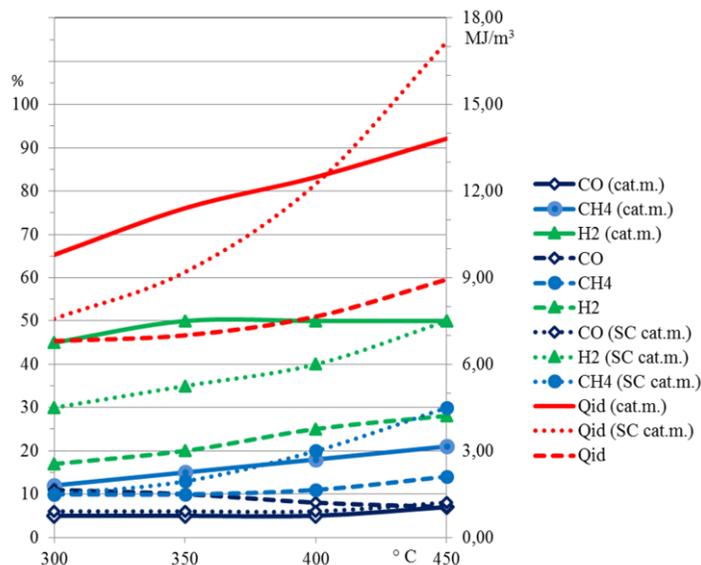

Fig.1. The content of combustible components in the gas from peat and semi-coke, % vol. The net calorific value of the gas from peat, MJ/m^3.

4 The material balances

During the thermal treatment of solid fuels the following products are formed: carbon residue (G_C); dry gas (G_Γ); resin and paragenetically moisture of fuel (G_{CM}); the mineral

part of fuel (G_M); the moisture of fuel, due to the operating moisture (G_W). Thus, the material balance is represented in the equation:

$$G_C + G_\Gamma + G_{CM} + G_M + G_W = 1 \qquad (1)$$

According to the equation form of material balance, Fig. 2 provides information about products obtained by the process of semi-coking (SC) and the low-temperature catalytic conversion (LTCC).

The equation form of material balance for the LTCC has the fundamental difference between the balance of semi-coking, as in the LTCC take part are additional entered steam (G_n) and catalytic additives (G_κ). Noting the features of the LTCC, should be considered that the part of the input high-temperature steam is involved in the reactions of hydrogen generation and reduction of ferrum oxides, so due to the steam there is a change of the material balance components, as the volume of gas and undecomposed steam. In this case, when compiling the material balances of LTCC should be considered the amount of injected steam. As for the catalytic additive, the volume of direct transformation does not occur, and rule of additive balance are not apply to them, so there is no need to consider the presence of catalytic additives during compiling the material balances of LTCC [5]. Thus, the equation (1) takes the form:

$$G_C + G_\Gamma + G_{CM} + G_M + G_W = 1 + G_\Pi \qquad (2)$$

Figure 2 shows the material balances based on dry mass of the low-temperature catalytic conversion of fuels, according to the equation (2).
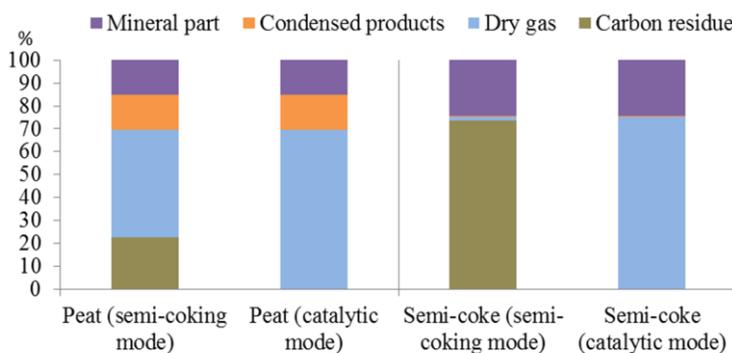

Fig. 2. The material balance of semi-coking and catalytic mode.

5 The heat balances

The heat balance is represented as the redistribution of the initial peat energy consumption by products of conversion. The determination of material balance is based on the quantitative data of material balance and the analysis of gas quality data. Figure 3 shows the results are based on dry ashless mass.

Obviously, that during the implementation of the semi-coking mode considerable part (about 30 %) of energy consumption accounted to the solid carbon residue. During the usage of peat as the initial feedstock, as in the semi-coking mode, and well in the catalytic mode, the part of the energy is distributed into a liquid fraction - resin. During the work

with semi-coke in the semi-coking mode allocated only the VOC products and energy distribution between the gas and the carbonaceous residue makes the proportion of about 1:1. In the case of catalytic mode, all organic matter is converted to the gas and, respectively, the entire power consumption of the initial fuel converts to net calorific value of the gas.
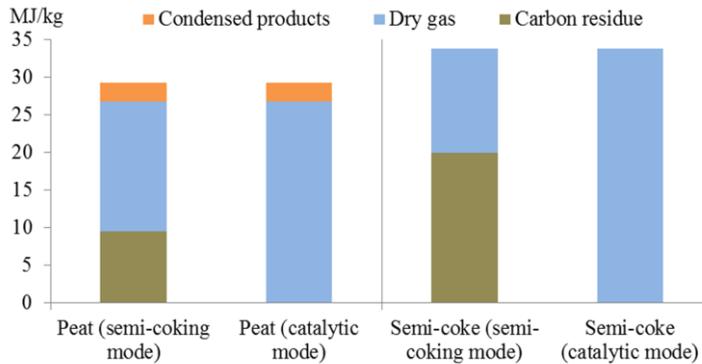

Fig. 3. The redistribution of power consumption initial sample by products of conversion.

6 Conclusion

Shown the results of studies of peat thermal conversion in the classic pyrolysis mode and the catalytic mode, characterized that in the process are injected iron oxide and steam with temperature of 300-450°C.

The intensity of the catalytic mode is low, which imposes a limitation for its industrial application. It seems appropriate to use this mode in power plants for small-scale power generation [6].

The embodiments of the conversion can be either manufacturing the hydrogen-rich gas, or combined gas and carbon product.

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