

# STUDY OF ELECTROPHYSICAL INTRASTRATAL GASIFICATION AT DIFFERENT COAL HEATING RATE

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**Abstract.** Experimental instrumental multi-method research, electrophysical intrastratal gasification of antracite with further definition of quantitative syngas composition and its combustion heat design at different heating rates. It was stated that concentration of carbon dioxide CO<sub>2</sub>, hydrogen H<sub>2</sub> decreases with heating rate increase in received syngas, and there is rise of carbon monoxide CO concentration. The results of the research showed that heating rate increase leads to a small rise of combustion heat as decrease of H<sub>2</sub> and CH<sub>4</sub> concentration is compensated with increase of CO.

## 1 Introduction

There are intensive scientific researches and industrial experimental works on coal gasification technology development in many countries around the world because of constant growth of prices [1] and decrease of natural gas deposits [2], and also high finding costs on new deposits, and the received products are able to fully change natural gas [4].

It is known [5] that one of the most perspective technologies of receiving gas from coal is underground gasification which is connected with physical and chemical processes in unmined coal layers the result of which is syngas [6] having good thermo physical properties for energetic and technological use [7,8].

Compared to natural gas received by method of underground gasification syngas contains the whole range of additional components: benzene hydrocarbon, coal-tar, phenol, methane, olefin, acetylene [9]. Use of syngas in energetics is the most ecologically clean one [10] compared to direct use of solid and liquid fuels at energetic, oil and gas, and chemical complexes. Syngas burning does not form detrimental impurities (sulphur dioxide, solid particles), and concentration of carbon oxides and nitrogen oxides is small [9]. Traditional ways of coal mining lead to ecological depletion of coal deposits, which is not common for underground gasification method [8]. Besides, cost value of received syngas is lower than the cost value of natural one [11].

Rate of reaction in coal layer is an important technological feature which influences the quality of received syngas by underground or intrastratal gasification method [9].

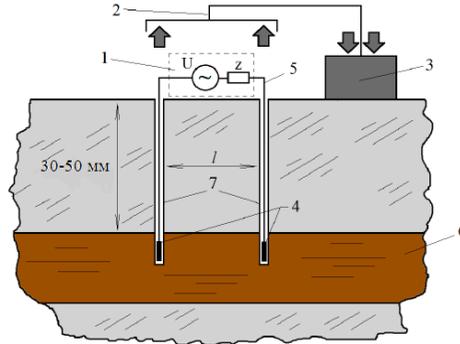
The aim of this work is an experimental research of syngas composition received by method of electrophysical intrastratal gasification at different antracite heating rate of "Krasnogorskoe" deposit.

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## 2 Experimental research

Research of underground coal gasification was done on the complex of experimental equipment intended for ways of development of electrophysical intrastratal gasification of solid fuels laying in the depth of 30 m (Fig. 1) [12, 13].



**Figure 1.** Principal diagram of electrophysical way of underground layers heating (1 – high voltage high-frequency generator, 2, 3 – system of gas separation, 4 – electrodes, 5 – high quality cables, 6 – layer of solid fuel, 7 – wells)

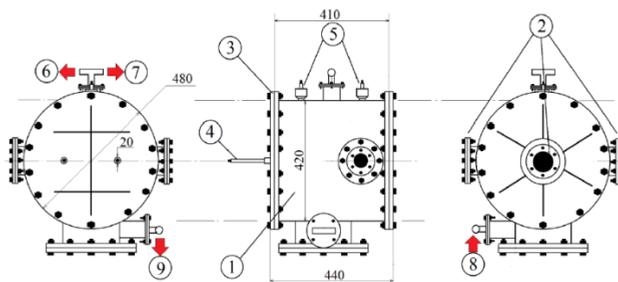
Research of solid fuel at ‘Krasnogorskoe’ deposit was done in this work. Element composition of samples coal of this type was defined with the help of scanning of electron microscope JEOL JCM-6000 and presented in table 1. There is also value of analytical moisture in a sample test in table 1.

**Table 1.** Element composition and analytical moisture

Element	C	N	O	Al	Si	S	Ca	Analytical moisture, %
Composition of element in mass %	82.14	11.26	4.04	0.51	1.36	0.08	0.61	1.21

There was used an installation for the experiment the main element of which was camera (pic. 2), where conditions for pressure and heat extraction close to the conditions of underground layer were created.

Camera presented in Fig. 3 has a cylindrical form with working volume 0.06 m<sup>3</sup> and pressure up to 5 MPa.



**Figure 2.** Experimental camera (1 – camera body, 2 – flanges, 3 – head plates, 4, 5 – electric inputs, 6, 7, 8, 9 – pipe headers)

Drilling of holes in the depth of 30-50 mm in the coal sample, which volume was 0.004 m<sup>3</sup>, and in which cylindrical electrodes with the diameter 10 mm from thermally-stable alloy (diffuse alloy of tungsten and copper) were input, was done before the experiment. Electrode spacing made 50 mm for all samples.

Pre-prepared sample of coal was put into experimental camera which was pressurized and filled with nitrogen N<sub>2</sub> with pressure 0.3 MPa. After that slow increase of voltage was input into electrodes connected to the samples from 1 to 10 kV. As a result of voltage increase in the sample there was an electric and thermal discharge [15], after that heating continued at constant voltage level by means of current regulation.

There were four experiments done during the experiment different from one another with heating rate.

Power input into samples was necessary for temperature increase in the center of electrode spacing on the surface of the sample with given heating rate at heating temperature of the coal sample [16]. The duration of the experiment was limited by the achievement of set value of maximum temperature 800 °C.

Characteristics of heating temperature range of coal samples are presented in table 2.

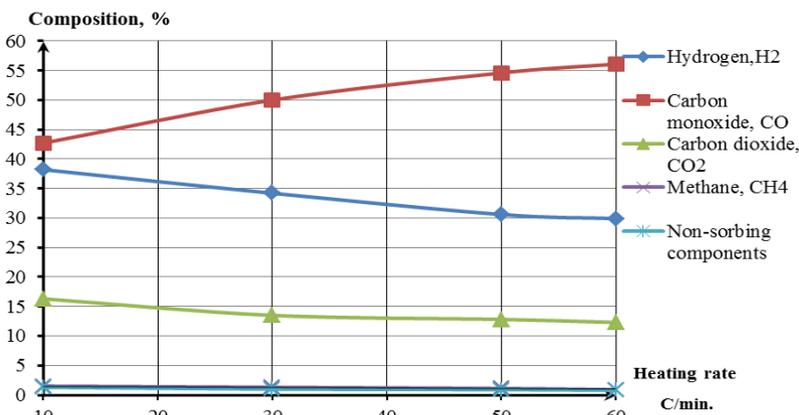
**Table 2.** Characteristics of heating temperature range

Number of range	1	2	3	4
Heating rate, °C/min.	10	30	50	60

During the experiment syngas sample was selected from the camera with the help of polymer air hose connected to the filter-regulator LFR-1/4-D-5M-MINI, which allows selecting gas sample without influencing the pressure in the camera and also deletes dust particles from gas. After it gas gets on chromatograph Agilent 7890A, for quantity analysis of syngas.

### 3 Results and their discussion

The results of experimental research on quantitative composition of syngas definition received from the above-presented coal sample by electrophysical intrastratal gasification at different heating rates are shown in Fig. 3.



**Figure 3.** Quantitative composition of syngas from anthracite at 'Krasnogorskoe' deposit

According to the results of quantitative composition of syngas definition presented in Fig. 3 we can conclude that with increase of heating rate carbon dioxide CO<sub>2</sub>, output decreases which positively influences syngas combustion heat. Increase of heating rate enables increase of intrastratal gasification intensification which leads to decrease of pyrolysis products interaction during thermo

destruction of coal with oxidizing environment in the form of moisture and oxygen discharge which are in coal samples.

There is decrease of hydrogen  $H_2$  and methane  $CH_4$  concentration with increase of coal heating intensiveness but carbon monoxide  $CO$  concentration increases. This phenomenon is caused by higher rate of oxidizing reaction of  $CH_4$  and  $H_2$  with moisture and oxygen  $O_2$  discharge from coal during their heating [9].

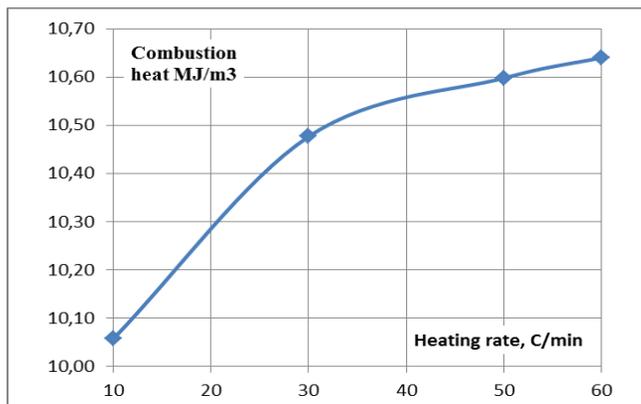
Non-sorbing components presented in pic. 4 characterize the composition of water vapor, nitrogen oxides residual elements, sulfur oxides, hydrogen sulphide and other ballast compounds in the received syngas. It should be noted that with increase of heating rate there is decrease of non-sorbing components concentration.

Knowledge of quantitative composition of syngas helps to identify combustion heat with the help of design method [17]:

$$Q = \sum_{i=1}^n Q_i \cdot C_i, \quad (1)$$

where  $Q_i$  – gas combustion heat of component  $i$ ,  $MJ/m^3$ ;  $C_i$  – share of component  $i$ .

The results of combustion heat design, syngas received from the presented coal samples at different heating rate are presented in Fig. 4.



**Figure 4.** Combustion heat syngas received by electrophysical intrastratal gasification of antracite at different heating rate.

According to the results presented in pic. 4 we can conclude that coal heating rate significantly influences the composition of received syngas and its combustion heat. There is intensive increase of combustion heat of syngas in the heating rate interval from  $10^{\circ}C/min.$  to  $30^{\circ}C/min.$  There is decrease of growth with further increase of rate in the interval from  $30^{\circ}C/min.$  to  $60^{\circ}C/min.$  The received effect of intensive increase of combustion heat in the first interval of the considered heating rate range was due to high increase of interaction rate of organic part of coal with oxidizing environment. As a result of this effect there is the highest rise of carbon monoxide  $CO$  in this interval.

## 4 Conclusion

The results of the experiments on definition of syngas composition by electrophysical intrastratal gasification showed that with the heating intensiveness increase of all presented coal types concentration of carbon dioxide  $CO_2$ , hydrogen  $H_2$  and methane  $CH_4$  decreases. On the basis of

above-described changes there is increase of carbon monoxide  $\text{CO}_2$ , which value compensates concentration of burning components and increases combustion heat index received from syngas.

On the basis of the received combustion heat values we can conclude that the efficiency of the underground coal gasification method is higher than that of the existing technology where air blowing is used [18].

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