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EXPERIMENTAL STUDY OF THE INFLUENCE OF CROSSING THE DISJUNCTIVE GEOLOGICAL FAULT ON THERMAL REGIME OF UNDERGROUND GASIFIER

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ЕКСПЕРИМЕНТАЛЬНІ ДОСЛІДЖЕННЯ ВПЛИВУ ПЕРЕХОДУ ДИЗЮНКТИВНОГО ГЕОЛОГІЧНОГО ПОРУШЕННЯ НА ТЕМПЕРАТУРНИЙ РЕЖИМ ПІДЗЕМНОГО ГАЗОГЕНЕРАТОРА

Purpose. Determining the impact of changes of the geological faults amplitude without breaking the continuity of coal seams and the temperature conditions of underground gasifier based on the experimental data during underground coal gasification.

Methodology. Methods of comparative analysis and mathematical modeling, experimental bench testing were used.

Findings. The scheme of determining the time of crossing geological fault according to thermocouples was developed. Based on this scheme the analysis of changes of the temperature during displacement amplitude of geological fault variation up to 0.9 of coal seam thickness was conducted. Average time deviation of crossing the fault plane of disjunctive geological fault with underground gasifier was received. Established values make it possible to determine the output of underground gasifier on stable operation regime by a temperature factor. Based on the experimental data it was defined that with increase in the amplitude of geological fault by more than 0.75 of coal seam thickness the process of underground coal gasification turns into the process of underground coal combustion. The results of the research will allow making adjustments to the calculation of heat balance of the gasification process.

Originality. It was found that with increase in the amplitude of disjunctive geological faults there appears additional loss of heat resulting from convection heat transfer in the place of coal seam fracturing and reducing of its emission due to changes in the combustion face of underground gasifier.

Practical value. Obtained results of bench experimental studies with sufficient precision for practical application can be used to determine the parameters of thermal balance and thermal regime of underground gasifier and provide an opportunity to expand the field of application of an underground coal gasification technology near geological faulting zones and potentially involve substandard deposits of hard coal for underground coal gasification. It will give an opportunity to receive generator gas, chemical products and power energy.

Keywords: *laboratory bench research, disjunctive geological faults, underground gasifier, thermal regime, fault plane*

Introduction. Coal is the main fossil fuel used in power generation. Coal makes about 70 % of world reserves of energy resources [1]. The concentration of coal seams in difficult mining and geological conditions at a considerable depth requires a comprehensive review of development opportunities [2]. There is a need to develop an alternative technology of extraction based on scientific investigation, consistent with the modern development of science and technology, which is cost-effective and environmentally safe and, most importantly, belongs to Clean Coal Technology [3]. Underground coal gasification (UCG) is such kind of technology.

For the conditions of Ukrainian energy and power sector, the research and substantiation of the possibility of alternative mining technologies are essential. Substantial deposits of coal can be converted to generators gas at a commercially reasonable level to solve problems of providing specific kind of energy and political aspects of the energy security of Ukraine, Poland, the Czech Republic and other countries where sufficient reserves of coal are located [4].

Underground coal gasification is a promising option for the future use of un-treated coal. UCG permits coal to be gasified in situ within the coal seam, via a matrix of wells. The coal is ignited and air is injected underground to sustain a fire, which is essentially used to "mine" the coal and produce a combustible synthetic gas which can be used for industrial heating, power generation or the manufacture of hydrogen, synthetic natural gas or diesel fuel.

An analysis of the recent research and publications. Over the last decades breakthrough in the field of underground coal gasification was obtained due to the strong interest in the development of alternative technologies of coal mining, due to the ever-increasing demand and fuel price [5].

Particular attention in this issue should be paid to the works of scientists from the National Mining University of Ukraine, Central Mining Institute (Poland), and scientific departments of companies "Linc Energy", "Carbon Energy", "Cougar Energy", "Wildhorse Energy", (Australia), "Ergo Energy" (Canada), "Lawrence Livermore National Laboratory", "Carbon County" (USA), "ENN Coal Gasification Mining Corporation", "Xinwen Coal Industry Group" (China), and others.

It is known that for the effective flow of thermochemical reactions in an underground gasifier it is necessary to maintain a high temperature in the oxidation zone and observe the rate of chemical reactions. At the same time, it is obvious that during crossing of the fault plane of geological fault additional heat loss arises that adversely affects the controllability of the process and insufficient substantiation for thermal regime of the underground gasifier causes a process shutdown of coal seam gasification.

Unsolved aspects of the problem. The issues of possibility of underground coal seam gasification with a large number of small-amplitude geological faults without coal seam fracturing, of determining the minimum distance between faults, unconsumed coal left by the faults of various types; impact the stability of wells near geological faults and thermal regime of underground gasifier have not been studied sufficiently yet.

Thus, the existing technologies of underground coal gasification process in the area of small-amplitude geological faults do not reflect the latest achievements of science and technology sufficiently. Based on the problems associated with crossing the disjunctive geological faults, it is clear that the study of new methods for the coal seam extraction in difficult geological conditions is now an urgent task not only for Ukraine but other countries around the world.

Objectives of the article are to set the influence of displacement amplitude of geological fault on thermal regime of underground gasifier based on laboratory investigation.

Presentation of the main research and explanation of scientific results. The investigations on the laboratory model explain the need for a thorough examination of possible transition of disjunctive geological dislocation with different fault plane amplitude and receiving the initial data for developing the methods for coal seam gasification in natural conditions.

The experimental laboratory unit was projected and patented in the department of underground mining of the National Mining University and built by "Neftemash" PJSC with financial support of the Ministry of Education and Science of Ukraine. The unit was installed and geared-up after the assistance of technical services of Donetsk electrical plant "Donetsksteel" and situated on the plant territory [1].

Control and measurement instrumentation for thermal regime fixation during coal seam gasification included temperature recorders which measured the temperature in a stationary mode (Thermocouple THA) and a dynamic mode (Pyrometer) (Table 1).

Table 1

Characteristics of control and measurement instrumentation for thermal regime fixation during coal seam gasification in laboratory conditions

Name of instrumentation	External view	Measurement parameters			Data output
		name	units	limits	
Stationary temperature recorder "Thermocouple THA"		*T*	°C	0–1000	Scren, Interface "TERA"
Dynamic temperature recorder "Pyrometr"		*T*	°C	0–1200	Screen

Using a pyrometer, which operates in a dynamic mode enabled to control the process of coal seam ignition. Temperature recorders were set in laboratory installation through special openings.

Formation of rock and coal massif on the laboratory experimental unit was carried out with maximum compliance of natural conditions of coal seam occurrence at various displacement amplitudes. Cementing material was used [6], based on research that is fully presented in the article [7]. Based on the design features of the laboratory installation, the coal was put into the model with a width of 1.75 m.

For air injection and gas output, in the boreholes there were left the hole with a width of 5 cm for each of them (according to the scale coefficient). Accordingly, the width of the coal seam, which was taken for further calculations, was 1.65 m (Fig. 1). To control the combustion face advance in coal seam on both sides of fault plane, ranging mark and thermocouple were set. The distance measurement begins from the middle of the so-called continuity of the coal seam.

General view of thermocouples that were set directly on the coal seam is given in Table 1, and options of their laying are listed in Table. 2.

The first stage of the experiment began with a coal seam ignition using red-hot pieces of coal that were previously subjected to heat treatment outside the experimental installation. After getting coal through a special side hole with diameter $d = 100$ mm, the air was applied directly on hot coals through an ignition pipe with a heat-resistant nozzle using a backup compressor. This led to the formation of fire ignition of the coal seam in the temperature range 505–545 °C, at a fixed average temperature – 525 °C. The ignition temperature of the coal seam in the reaction channel was controlled with a pyrometer. Rate of blast amounted 2–3.5 m^3/min, pressure – 0.3 MPa.

Taking into account fairly rapid rate of reaction channel burning in the coal seam, after 25 minutes of continuous supply of air blowing through ignition hole (Fig. 2, *a*) there was a gradual transition of blast blowing through the main system (Fig. 2, *b*). After the appropriate steps for the transition of blast supply, according to the methodology of the study [8], the rate of burning reached 0.7 m/h, resulting in a gradual increase in pressure up to 0.5 MPa.

During coal ignition the periodic reverse of blowing mixture swelling was carried out. In the process of

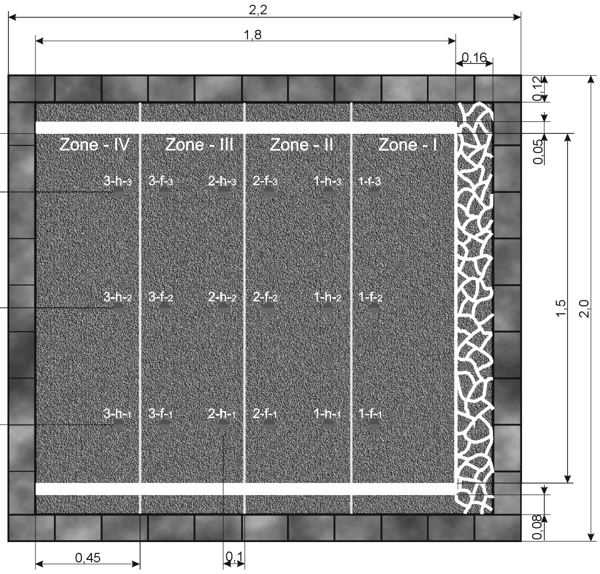

Fig. 1. The model of coal seam formation with thermocouples and ranging mark setup with account of design features of test bench

Table 2

Parameters of laying of ranging marks and thermocouple

Name of ranging mark and thermocouple	The hight of laying, m	Distance from ranging mark and thermocouple, m		Name of ranging mark and thermocouple	The hight of laying, m	Distance from ranging mark and thermocouple, m	
		to an air injection hole	to production hole			to air injection hole	to production hole
Handing wall				Footwall			
Zone I–II, $h_{fp} = 0.5$ m							
1-h-1	0.3	0.25	1.25	1-f-1	0.2	0.25	1.25
1-h-2	0.3	0.75	0.75	1-f-2	0.2	0.75	0.75
1-h-3	0.3	1.25'	0.25	1-f-3	0.2	1.25	0.25
Zone II–III, $h_{fp} = 0.75$ m							
2-h-1	0.35	0.25	1.25	2-f-1	0.3	0.25	1.25
2-h-2	0.35	0.75	0.75	2-f-2	0.3	0.75	0.75
2-h-3	0.35	1.25	0.25	2-f-3	0.3	1.25	0.25
Zone III–IV, $h_{fp} = 0.9$ m							
3-h-1	0.375	0.25	1.25	3-f-1	0.35	0.25	1.25
3-h-2	0.375	0.75	0.75	3-f-2	0.35	0.75	0.75
3-h-3	0.375	1.25	0.25	3-f-3	0.35	1.25	0.25

a

b

Fig. 2. Air injection during coal seam ignition:
a — through the ignition outlet; b — through the injection system

reverse, the combustion source moved actively to meet the air flow. In a 1 hour and 30 minutes, burning of the reaction channel spread over almost the entire length of the combustion face. However, the transition to the gasification regime was impossible because of the variable yield of smoke gasses and combustible gases.

Despite the considerable development in the combustion source in the gasifier, the gas temperature at the outlet of the experimental unit was relatively small (~70 °C) by that time. Quite a large amount of heat was wasted on rocks of roof heating, evaporation of inherent moisture of rock massive and thermal preparation of coal. Change-over to a mixed mode of compressor — smoke exhauster, which began in 1 hour 30 minutes after coal seam ignition, allowed reducing the pressure to 0.3 MPa and increase the speed of combustion up to 1.1–1.2 m/h.

At the end of the second hours of burning of the reaction channel, the temperature of output gases increased to 100 °C together with a sharp reduction of carbon dioxide CO_2 to 7.3 %. In addition to this, tendency to the effective development of the reaction channel was observed with increase in CH_4 to 1.6 %, CO – 5.5 %, and H_2 – 3.6 % and reduction of O_2 to 5.6 %. Gradual increase in the quantity of combustible gases convincingly proves the completion stage of the reaction channel formation. After the eventual burning of reaction channel, the gasification process turned to forming the reaction zones in gasification channel, which lasted for the next hour.

Laboratory simulations were conducted to gain a fundamental understanding of the coal gasification processes. Analyses were performed to identify the most influential parameters for gasification performance.

Control of the gasification process on laboratory unit was carried out by injected air from the first compressor through the pipeline system to the reaction channel. Air was injected to the oxidation zone where exothermic reactions occur with the release of the heat to the gasification channel. In reducing zone where endothermic chemical reaction occur, the heat is absorbed in gasification channel. That is why it is necessary to calculate heat and material balance for physical equilibrium velocity and kinetics of chemical reactions in the underground gasifier.

Combined injected air supply in pulsating regime allowed passing the ignition regime in a short time and reaching the regime of stabilization. In oxidation zone, the multiphase chemical reaction between oxygen, which has been supplied in the gasifier, and carbon (the main part of coal seam) provide heat generation to rather high temperature [9]. Heat generation provides endothermic reaction behavior of carbon dioxide (CO_2) recovery and water vapor decomposition.

A high-temperature field with high inertia and high heat spread area is formed just after the beginning of coal seam ignition in spite of significant heat loss in heating rocks surrounding the gasifier [10]. In general, the temperature along the length of the reaction channel is not distributed evenly. In the oxidation zone, where the intense combustion reactions with heat liberation occur, temperatures vary between 600–900 °C gradually increasing at close to the transition zone with maxim value 900–1200 °C [11]. Dynamics of the temperature in the area of restoration zones is conditioned by the prevalence of heat loss under endothermic reactions which reduces heat distribution in the environment [12]. Temperatures in this area make 500–750 °C.

Oxidation or oxygen zone is an energy source and output products for the subsequent formation of combustible components of the underground coal gasification. A characteristic feature of underground coal gasification channel is that in the oxidation zone in addition to coke also volatile matter is present and moisture is inherent in coal and rocks around the coal seam.

The enhancement of the total process of carbon gasification theoretically depends on both the rate of chemical reactions and the enhancement of injected air supply and extraction of gasification product. The role of these heterogeneous factors depends on specific conditions of the gasification process. As a result of interactions of carbon with oxygen, oxide and carbon dioxide are formed. At low temperatures, the rate of chemical reactions between carbon and oxygen is low, and the total rate of the process is determined by the speed of chemical reactions.

During the investigation the reagents of blast passing through three reaction zones formed generator gases comprising a combustible mixture of carbon oxide (CO), hydrogen (H_2) and methane (CH_4). The proportion of these gases varied depending on the type of blowing and time from the beginning of the study.

To monitor the combustion face advancing thermocouples were used measuring the temperature range from 0 to 1000 °C. Using a signal converter and the ability to connect to the interface through messengers successively COM-port RS-232, temperature data were recorded in the TERA "Devices Systems" program using cross-platform database Firebird 2.1. In the process of conducting the research, sensors that were placed on the basis of the coal seam, fixed the temperatures in a steady mode with a step of 15 minutes. For the sake of convenience of analyzing the temperatures, the thermo-couples were divided into three groups. The first group and the following groups include 6 thermocouples, 3 of which were in the handing wall and the next 3 were in the footwall of fault plane (Fig. 1).

In the zone I–II, where the first system of sensors was actually situated, the temperature at the beginning of the experiment ranged from 21 to 23 °C and did not change within 1 hour and 30 minutes. With gradual advance of combustion face, the thermocouple 1-f-2 fixed a rapid increase in temperature (Fig. 3) for the first time.

At 4 hours and 15 minutes, the temperature of coal seam near the thermocouple exceeded the measurable limit of 1000 °C, so that automatically disabled it to prevent overheating of the heating element. During the 1 hour and 15 minutes data on this thermocouple not acted.

The temperature of thermocouple 1-h-2 in the gasifier was close to 1000 °C, with a maximum value – 978 °C after 6 hours of the experiment. Analysis of raising temperature scale for all thermocouple proves uniform crossing of geological dislocation with fault plane h_{fp} = 0.5 m. Besides, the critical dependence of lowering temperature after underground gasification was found. Analysis of temperatures regarding chemical zones of experimental underground gasifier was not carried out because of the cyclic reverse of injected air flow. Despite the lack of clear zones, use of graphs of temperatures permitted determining time at which crossing of geological fault plane occurred.

Based on the dependence of temperature field distribution in the rock massive it follows that the temperature in a definite place of rock massive will have the gradual character of the increase until approaching the combustion face up to this point with maximum value at the time of occurrence of thermochemical reactions (Fig. 4).

Accordingly, with the same linear speed of combustion face advance the same changes will occur in the following places. The basic task of data interpretation was fixing the temperature at which analysis of the research will be performed. The essence of the proposed method of determining the time at which combustion face of underground gasifier crosses the zone I–II comes down to determining the average temperatures, the value of which exceeds 500 °C. Taking into account the subjectivity of this method, determining the average value of temperature was carried out using all thermocouples data. Moreover, firstly we found the average temperatures between the first thermocouple whose value reached 500 °C and the last thermocouple with the same indicator. Accordingly, having the data of thermocouples 1-f-2 of 3 hours and 40 minutes and the data of thermocouple 1-h-3 of 6 hours and 25 minutes we obtain the average value of 4 hours and 53 minutes.

After determining the average values for each pair of thermocouples the average time to cross the fault plane of geological dislocation with combustion face was determined. In this analysis, the relevant average value was 4 hours and 57 minutes. Obviously, an average value between the two values is 4 hours and 55 minutes of the experiment, which coincides with the calculated parameters of gasification and makes 98.3 %. It should also be noted that the thermal factor

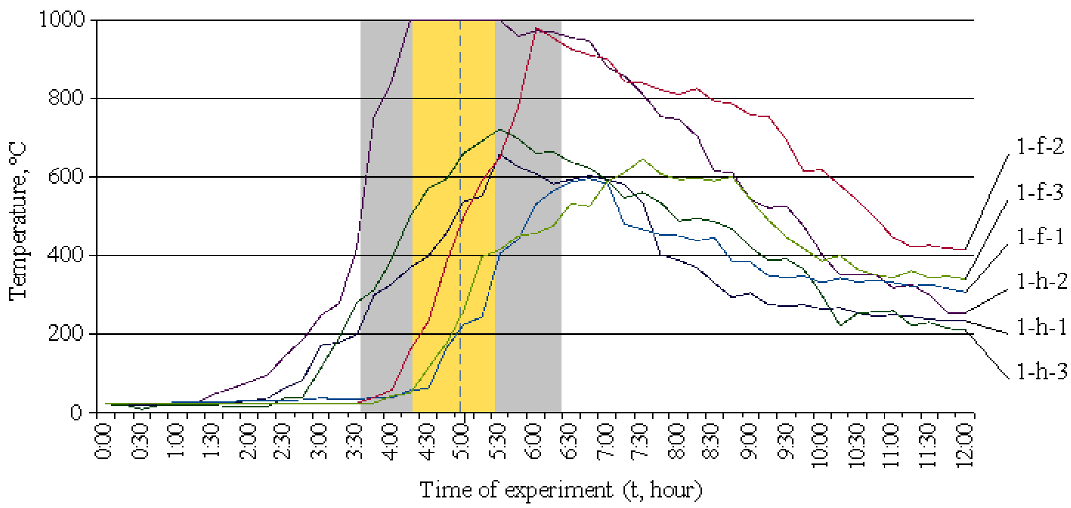

Fig. 3. Graphs of temperature change in the zone I–II (h_t = 0.5 m)

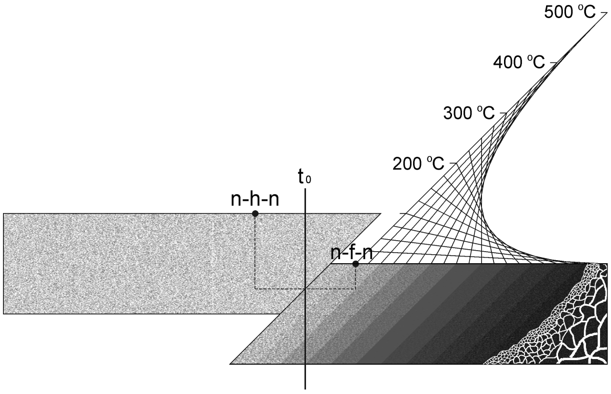

Fig. 4. The scheme of determination the time of crossing geological fault according to thermocouples

the geological dislocation h_{fp} = 0.5 m was crossed with little heat loss for a specified period of time.

With the stabilization of the regime of gasification in the zone II, after 6 hours and 30 minutes of the experiment gradual rising of the temperature at the thermocouple 2-f-2 was recorded, and in 15 minutes temperature increase occurred to thermo-couple 2-f-3. Here, during the following 2.5 hours the temperature increases up to 600 °C (Fig. 5).

Using the above-mentioned approach to determine the time of crossing fault plane of geological dislocation, it was found out that in the zone II–III crossing fault plane with underground gasifier took place between 9 hours and 55 minutes and 10 hours and 10 minutes. However, the temperature distribution in the zone II–III, largely coincides with the spread in the zone I–II. This is evidenced by the values of temperatures in oxidation and reducing zones.

In the zone I–II, the lowest maximum temperature was 568 °C, and the highest maximum temperature was 736 °C, while in the zone II–III these indicators were 567 and 687 °C respectively. The difference in the time when reaching 500 °C in the same zones is 35 minutes, which in terms of time is 3 hours and 15 minutes and 2 hours and 40 minutes respectively.

The latest fault plane was characterized by continuous disjunctive displacement amplitude – $h_{f.p}$ = 0.9 m. In this case, the beginning of the temperature increase in the footwall (thermocouples 3-f-1, 3-f-2 and 3-f-3) was roughly within the same time frame as in the previous displacement of the coal seam. However, the time to overcome such displacement increased significantly. Under the following conditions, the use of the method proposed before has no significant result. Graphical display of temperature changes in the zone III–IV is shown in Fig. 6.

Relatively lower maximum temperatures fixed with thermocouples were typical for zone III–IV both in the handing wall and in the footwall. This reduction in temperature could be caused by an increase of goaf and consequently heat losses in fractured rock massif.

Taking into account the sequences of the study, possible time of crossing the fault plane was determined. According to the results of averaging it was found that crossing occurred at approximately at 15.50, almost one hour late from the calculated time. The delay from the calculated speed was apparently due to a significant reduction of continuity fault plane of the coal seam. It is obvious that with time delay the temperature in the hanging wall of the zone IV still reached the required values for gas generating and balance of thermal regime of underground coal gasification process.

A more detailed analysis of changes in the temperature regime in the zone IV is provided by the data on gas generation from 15 to 20 hours of gasification of coal [1].

Having processed the data of distribution of temperatures in the rocks of the roof above coal seam in the zone of geological dislocation and having the average time of crossing the fault plane with combustion face on temperature sensors, we can get a complete picture of the differences in the results compared to the estimated parameters of coal seam gasification on laboratory installation.

Considering the conducted research for each geological dislocation, the average time of potential deviations of crossing interface was found with variable amplitude of geological dislocation. Based on the results we receive a graph of average time deviation of cross-

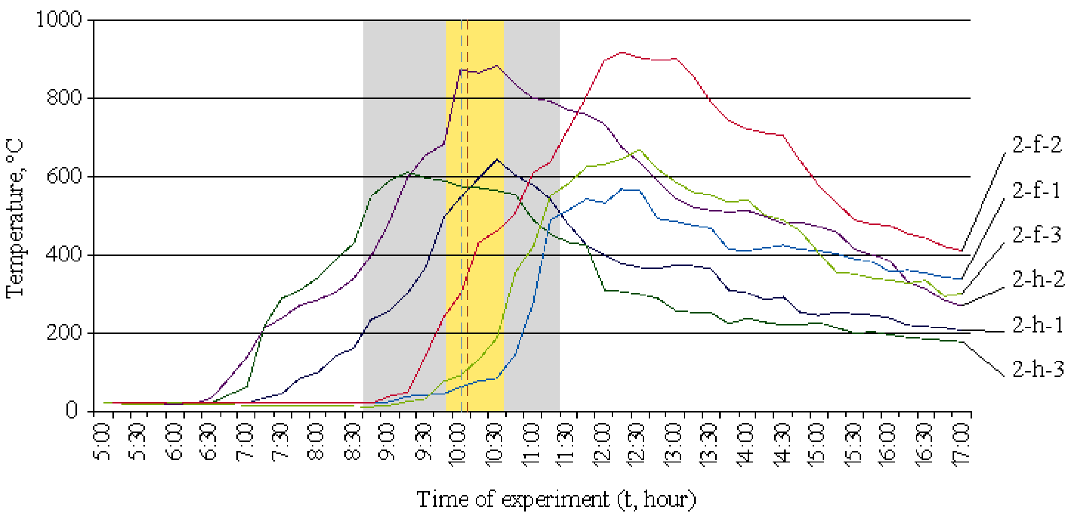

Fig. 5. Graphs of temperature change in the zone II–III (h_t = 0.75 m)

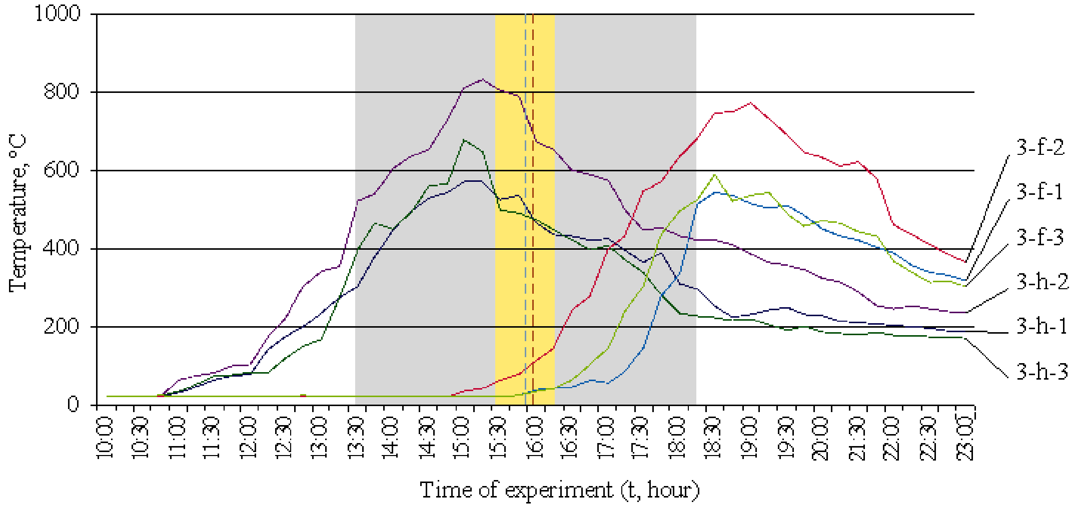

Fig. 6. Graphs of temperature change in the zone III–IV (h_t = 0.9 m)

ing the fault plane of disjunctive geological fault with underground gasifier which is shown in Fig. 7.

Analyzing Fig. 7, we should note that the graph that is based on data analysis of average temperatures $\bar{T}$, tends to delay toward to the combustion compared to the calculated time of gasification. At the same time, alignment of these parameters is compensated by the average analysis regarding the percentage of CO reduction [1].

Research conclusions and recommendations for further research in this area. On the basis of the research, the authors found that during underground coal gasification in the zones near geological faults due to heat transfer additional heat loss occurs, and with increasing amplitude of geological fault and the time of gasification such losses are constantly increasing.

This is not the heat loss to the environment that counts but reduction in its release due to a sharp decrease of a combustible face in the reaction channel. In essence, when large amplitude of geological fault occurs reigniting of a coal seam and the process of underground coal gasification turns into an underground coal combustion process.

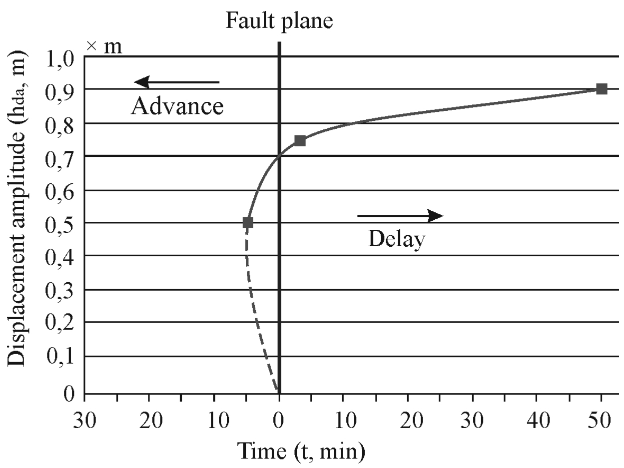

Fig. 7. Graph of average time deviation of crossing the fault plane of disjunctive geological fault with underground gasifier

Based on the dependence of temperature field distribution in the rock massive it follows that the temperature in a definite place of rock massive will have the gradual character of the increase until approaching a combustion face up to this place with maximum value at the time of occurrence of thermochemical reactions.

The analysis of temperature changes in the gasifier while crossing the disjunctive geological dislocation depending on geological fault plane makes it possible to determine the change in a thermal regime of an underground gasifier.

The distribution of the temperature along the length of the reaction channel is related to its length, section, a quantitative and qualitative composition of injected mixture and generated gases, the degree of strain and temperature indicators of rocks containing reaction channel of the gasifier.

The intensity of crossing the geological fault is associated with a balanced supply of injected mixture. According to the given geometric heterogeneity of coal seam, it is necessary to perform a recalculation of mass and thermal balance and employ a manual mode of gasification process.

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Мета. Визначення впливу зміни амплітуди зміщувача геологічних порушень без розриву суцільності вугільного пласта на температурний режим підземного газогенератора на основі отриманих експериментальних даних при застосуванні технології свердловинної підземної газифікації вугілля.

Методика. Застосовані методи порівняльного аналізу, математичного моделювання, експериментальні стендові дослідження.

Результати. Розроблена схема визначення часового моменту переходу геологічного порушення за температурними датчиками, на основі якої проведений аналіз зміни температур при варіації амплітуди зміщувача геологічного порушення до 0,9 потужності вугільного пласта. Отримана залежність усередненого часового відхилення переходу зміщувача геологічного порушення підземним газогенератором. Встановлені величини дають можливість визначити час виходу підземного газогенератора на стабільний режим роботи за температурним фактором. На основі отриманих експериментальних даних встановлено, що при збільшені амплітуди геологічного порушення більше 0,75 потужності вугільного пласта процес підземної газифікації переходить у процес підземного спалювання вугілля. Результати досліджень у повній мірі дадуть змогу внести корективи до розрахунку теплового балансу процесу газифікації.

Наукова новизна. Встановлено, що зі збільшенням амплітуди диз'юнктивного геологічного порушення виникають додаткові втрати тепла за рахунок конвекційного теплообміну в місці розриву вугільного пласта та зменшення його виділення у зв'язку зі зміною дзеркала вогневого вибою по площині зміщувача.

Практична значимість. Отримані результати стендових експериментальних досліджень із достатньою для практичного застосування точністю можуть використовуватися для регулювання параметрів теплового балансу та теплового режиму підземного газогенератора, дають можливість розширити область застосування технології свердловинної підземної газифікації вугілля в зонах геологічної порушенності гірського масиву та, у перспективі, залучати до відпрацювання некондиційні поклади кам'яного вугілля для отримання генераторного газу, хімічних продуктів та теплової енергії.

Ключові слова: *стендові дослідження, диз'юнктивні геологічні порушення, підземний газогенератор, температурний режим, зміщувач*

Цель. Определение влияния изменения амплитуды сместителя геологических нарушений без разрыва сплошности угольного пласта на температурный режим подземного газогенератора на основе полученных экспериментальных данных при применении технологии скважинной подземной газификации угля.

Методика. Применены методы сравнительного анализа, математического моделирования, экспериментальные стендовые исследования.

Результаты. Разработана схема определения временного момента перехода геологического нарушения по температурным датчикам, на основе которой проведен анализ изменения температур при вариации амплитуды сместителя геологического нарушения до 0,9 мощности угольного пласта. Получена зависимость усредненного временного отклонения перехода сместителя геологического нарушения подземным газогенератором. Установленные величины дают возможность определить время выхода подземного газогенератора на стабильный режим работы по температурному фактору. На основе полученных экспериментальных данных установлено, что при уве-

личении амплитуды геологического нарушения более 0,75 мощности угольного пласта процесс подземной газификации переходит в процесс подземного сжигания угля. Результаты исследований в полной мере позволят внести коррективы в расчет теплового баланса процесса газификации.

Научная новизна. Установлено, что с увеличением амплитуды дизъюнктивного геологического нарушения возникают дополнительные потери тепла за счет конвекционного теплообмена в месте разрыва пласта и уменьшение его выделения в связи с изменением зеркала огневого забоя по плоскости сместителя.

Практическая значимость. Полученные результаты стендовых экспериментальных исследований с достаточной для практического применения точностью могут использоваться для регулирования параметров теплового баланса и теплового режима подземного газогенератора, дают возможность расширить область применения технологии скважинной подземной газификации угля в зонах геологической нарушенности горного массива и, в перспективе, привлекать к отработке некондиционные запасы каменных углей для получению генераторного газа, химических продуктов и тепловой энергии.

Ключевые слова: *стендовые исследования, дизъюнктивные геологические нарушения, подземный газогенератор, температурный режим, сместитель*

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COMPUTER SIMULATION OF FLUID MECHANICS AND HEAT TRANSFER PROCESSES AT THE WORKING FACE OF BOREHOLE ROCK

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КОМП‘ЮТЕРНЕ МОДЕЛЮВАННЯ ПРОЦЕСІВ ГІДРОДИНАМІКИ ТА ТЕПЛООБМІНУ НА ВИБОЇ СВЕРДЛОВИНИ, ЩО БУРИТЬСЯ

Purpose. The numerical study of the drill mud flow speeds field at the working face of a borehole. Substantiation of methodology to calculate the convection heat transfer rates on the surface of a diamond core bit during its cooling.

Methodology. Computational fluid dynamics methods (CFD modeling) were used in the course of the study.

Findings. The physical and mathematical models of fluid mechanics and heat transfer processes at the working face of a borehole during its boring with diamond core bits are suggested herein. The field of circulating drill mud flow speeds around the diamond core bit at the drilling of rock formation was obtained. Regarding the convective heat exchange, the computer simulation demonstrated that a notable change of flow speed field during the boring occurs throughout the height of the bit. In the course of the bit rotation the flow speed field can be considered uniform alongside the azimuthal direction. The ultimate non-uniformity of the speed field is revealed in the water hole passages of the drilling core bit, which results in its heavier wear. Based on the distribution speed calculation results, the convection heat transfer coefficients were defined throughout the height of the drilling core bit. The study revealed that, owing to significant acceleration of the flow, the most intense heat exchange processes took place in the waterhole passages.

Originality. The theory of fluid mechanics processes at the working face of a borehole during the boring was further developed. New data were obtained on the distribution of the flow speed field and pressure field in the circulating fluid at the bottom-hole area. The non-uniform nature of the fields was demonstrated herein. It is shown that, due to the locally uniform field of speeds distribution, it is possible to assume that the bit convection heat exchange ratios are constant in the certain areas.

Practical value. The outcomes of the fluid mechanics field modeling can be used for determination of the optimum sizes and shapes of the waterhole passages in the course of designing new boring tools and equipment. The obtained heat exchange ratios enable to carry out calculations of temperature fields in the crown bit body, which is necessary to establish the resource and power saving modes of drilling.

Keywords: *drilling core bit, drilling, fluid mechanics, computing modeling, heat exchange*