РОЗРОБКА РОДОВИЩ КОРИСНИХ КОПАЛИН

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REVISITING POSSIBILITY TO CROSS DISJUNCTIVE GEOLOGICAL FAULTS BY UNDERGROUND GASIFIER

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ДО ПИТАННЯ ПЕРЕХОДУ ДИЗ'ЮНКТИВНИХ ГЕОЛОГІЧНИХ ПОРУШЕНЬ ПІДЗЕМНИМ ГАЗОГЕНЕРАТОРОМ

Purpose. To justify the opportunities to cross the disjunctive geological faults without full coal seam fracturing by underground gasifier, basing on the established time dependencies of underground gasifier output to an effective gasification regime applying the technology of borehole underground coal gasification.

Methodology. The changing dependency of time when the underground gasifier reaches the regime of stabilization during underground coal gasification was found with a laboratory experimental unit.

Findings. The dependencies of fault plane amplitude in geological fault on the distance at which the gasifier reaches the regime of stabilization on the total output of combustible gases and their heating value were received. The change of the dependency of the coefficient of gasification enhancement, which is influenced by the thermochemical rate processes in reaction channel of the underground gasifier, is presented. The approach to transfer the results of the experimental investigation in natural conditions based on geometric and time simplifications was offered. The results of the research will allow adjusting the calculation of material and heat balance of the gasification process to determine the optimal qualitative and quantitative composition of injected air.

Originality. The time of underground gasifier reaching the regime of stabilization is determined by the rate of non-fracturing of a coal seam and regulated by the reaction channel advance and balanced supply of reagents blast.

Practical value. The results of the experimental investigations are precise enough for practical application. They can be used to determine the output parameters allowing the process to reach the regime of stabilization during underground coal gasification. It gives the possibility to expand the use of underground coal gasification technology in geological fracturing zone and can be potentially involved in mine development of substandard coal reserves for energy and chemical generator gas production, chemicals and heat manufacture.

Keywords: *laboratory research, disjunctive geological faults, underground gasifier*

Introduction. Coal is the main fossil fuel used in power generation. According to the World Energy Resources 2013 on average 60% of global substandard coal reserves is located in difficult mine and geological conditions, including the geological fracturing zones development of which would allow to increase the time of its consumption due to additional production and integrated use of the following 40–60 years. International and local experience shows that traditional coal mining in the areas of geological fracturing is unviable because of the high cost of coal produced, low labor safety of miners and gas-dynamic phenomena that occur near the affected zones.

The concentration of coal seams in difficult mining and geological conditions at a considerable depth requires a comprehensive review of development opportunities. There is a need to develop an alternative technology of extraction that will be based on scientific investigation, consistent with the modern development of science and technology, cost-effective and environmentally safe and, which is the most important, belong to Clean Coal Technology. Such technology is underground coal gasification (UCG). An underground coal gasification is a promising option for the future use of un-worked 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 [1].

For the conditions of Ukrainian energy and power sector, the research and justification the possibility of alternative mining technologies are essential. Substantial deposits of coal can be converted to generators gas turn-on commercially reasonable level, to solve problems of providing specific kind of energy and political aspects of the energy security.

The analysis of recent research and publications. The last decade's 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. Several generations of local and foreign scholars have worked in the field of development and implementation of the environmentally friendly technology of underground coal gasification of coal seams.

The works by V.I. Bondarenko, H.I. Hajko, R.O. Dychkovskyi, V.N. Kazak, O.V. Kolokolov, H.V. Orlov, I.A. Sadovenko, P.V. Scafa, Ju.V. Stefanyk, M.M. Tabachenko, V.S. Falshtynskyi, L. Yang, G. Perkins, S. Daggupati, 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 deserve particular attention.

They investigated geomechanical, thermodynamically, thermochemical, hydrogeological and other aspects of coal seams gasification that were in relatively advantageous geological conditions of occurrence [1–4], while studying the gasification process in the zones of geological fracturing practically not carried out in certain cases hitting underground gasifier in the zone of influence of geological faults where they adversely affect the handling process, as they most often are unpredictable. In case of insufficient detailed exploration, the study of technology options for their transition led to stop the process of underground coal gasification.

Unsolved aspects of the problem. The possibility of coal seams gasification with a large number of small-amplitude geological faults without coal seam fracturing, determines the minimum distance between faults, unconsumed coal left by the faults of various types; the impact of the stability of wells near geological faults, etc. currently is poorly understood.

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

The objective of the article is to set the time when the gasification process reaches the regime of stability with variable fault plane amplitude of geological dislocations on the basis of laboratory investigation.

The presentation of the main research and the explanation of scientific results. The investigations on the laboratory model explain the need for the thorough examination of possible transition disjunctive geological dislocation without full coal seam fracturing at different values of dis-placement amplitude and the initial data acquisition for development the methods for coal seam gasification in natural conditions.

The experimental laboratory unit is projected and patented in the department of underground mining of the National Mining University and built by PJSC "Neftemash" at the sponsorship by the department of education and science of Ukraine. Installed and geared-up after the assistance of technical services of Donetsk electrical plant "Donetsksteel" and situated on the plant territory [5].

The processes occurring in real underground conditions are extremely difficult, so it is almost impossible to choose a universal theory that takes into account the comprehensiveness of the process by looking at the system of phase transitions. Accordingly, in practice, most often the studies are conducted based on significant factors that are crucial for a certain amount of time to process. The air injected from the first compressor through the pipeline system to the reaction channel carries out control of the gasification process on laboratory unit. The air inject in oxidation zone where reaction behavior is carried out by exothermic chemical reaction releases the heat in gasification channel. In reducing zone where reaction behavior is carried out by endothermic chemical reaction absorb the heat 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 in a short time pass the ignition regime and reaches the regime of stabilization. In the 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 high enough temperature. Heat generation provides endothermic reaction behavior of carbon dioxide (CO_2) recovery and water vapor decomposition.

Oxidation or oxygen zone is an energy source and output products for the subsequent formation of combustible components of the underground coal gasification [6]. A characteristic feature of underground coal gasification reaction channel is that in the oxidation zone addition to coke also present volatiles matter and coal inherent moisture and rocks around the coal seam.

The enhancement of the total process of carbon gasification theoretically depends both on the rate of chemical reactions and on the enhancement of injected air supply and the extraction of gasification product. The role of these heterogeneous factors depends on specific conditions of the gasification process. The interactions of carbon with oxygen result in oxide and carbon dioxide. 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 comprised the combustible mixture of CO, H_2, and CH_4. The proportion of these gases varied depending on the type of blowing and the time from the beginning of the study. Generator gases move out along the direction of airflow. Fig. 1 is the concentration of generator gases measured by gas detectors "Gasboard 320 L" and "BX-170" that work in dynamic and manual mode.

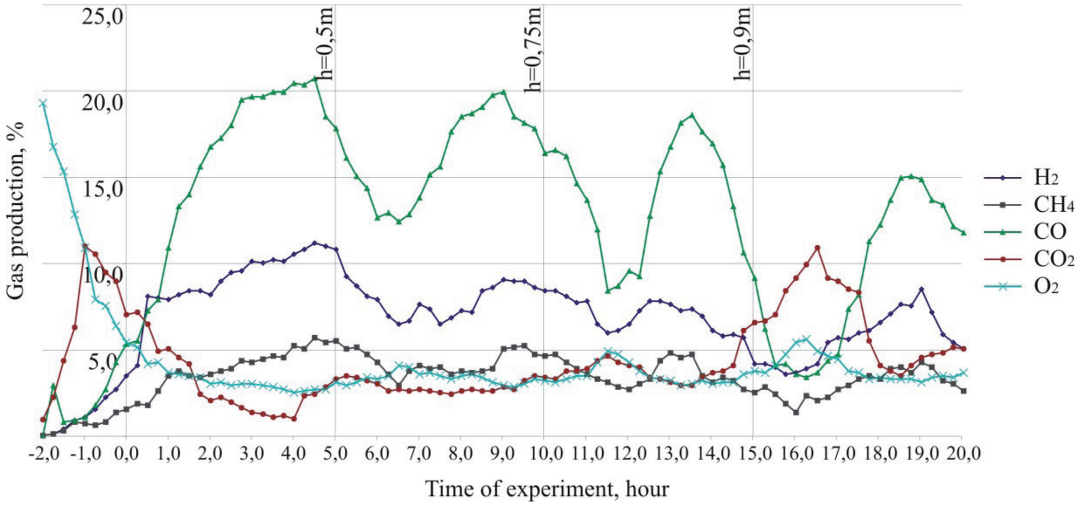

Fig. 1. Generator gas output during the experiment

Since experimental studies of underground coal gasification include coal ignition, followed by reaction channel formation in oxidation and reducing zone with a gradual transition to a stable regime of gasification process, fig. 1 has the marks of the conventional division between these processes.

After five hours of the efficient gasification process, we fixed a decrease in all indices of combustible gases, indicating the approaching of fault plane and disbalance of material and heat balance. This situation during the experiment promoted the deployment of the experiment gasification process transfer to manual control mode. There was a gradual reduction of injected air supply in the zone of reaction channel to prevent the formation of the high-concentration of unreacted part of oxygen in the recovery zone. For the calculation of the materially thermal balance of BUCG, the special program was utilized. The calculation algorithm includes thermochemical conversions of solid fuel into gas and condensed fluid in the conditions of the elementary composition of a coal seam.

After gasification stabilization, the process moved in the planning mode of gasification. During the experiment, with a certain step, such intermittent effect was observed three times. The readiness to the development of such events has enabled early steps to predict the alarm appearance during the experimental investigation. The ratio CO/CO_2 in generator gases depends on kinetic and hydrodynamic conditions of carbon combustion and significant effect not only on the process of gas production, but also on the intensity of oxygen consumption and correspondingly expansion of oxidation zone.

Throughout the experiment, there was a high concentration of CO in the generator gases with respect to CO_2, which is explained by quite effective chemical reactions under high temperatures in an oxidation zone and a small amount of water vapor and gradual reduction of O_2 shows the number of balanced injected air blast supply. The exceptions are the areas with the crossing of the fault plane. Here there was a dramatic decrease of the volume of combustible generator gases and smoky gas increase. This is especially true for transition zone III–IV in which at 16 hours 30 minutes from start the gasification the concentration of CO_2 reached 11.3 %, O_2 – 5.6 %. The formation of so-called reduction of CO roughly coincides with the presence of geological faults, although there is some disagreement with the calculated parameters.

Analyzing the decrease in the concentration of CO, it should be noted that the so-called lowering of the percentage content of carbon monoxide occur before displacement amplitude of disjunctive geological fault, because the gasification of coal seam is carried out not only in the length of the reaction channel. The chemical zone of oxidation, recovery and drying was formed in the coal seam perpendicular to the reaction channel. The disturbance of these zones provides the variation of material and heat balance, coursing time degrades of the combustible generator gases output.

According to the research results [7], the reduction of qualitative and quantitative composition of the generator gases was stipulated by varying the power of the coal seam, including the presence of a disjunctive fault. Geological anomalies greatly influence the redistribution of heat in the reaction channel of underground gasifier affecting the initial concentration of gas generator [8].

Making parallels between the obtained concentrations of combustible and non-combustible generator gases (fig. 1) there is a substitution of some other. In the zone I and reduce the concentration of H_2, CH_4, CO started at 4 hours 45 minutes in the zone II – at 9 hours 15 minutes, while zone III – 13 hours 45 min from the beginning of gasification process on laboratory unit.

The confirmation of the linear velocity of combustible face advance made it possible to analyze timing violations of crossing the geological fault by underground gasifier with access to effective regime of gasification on the total output of combustible generator gases and their heating value during the experiment (fig. 2).

The definition of the time when underground gasification processes reach the regime of stabilization requires phased implementation analysis of experimental data. First, this analysis was performed on the total output of generator gases.

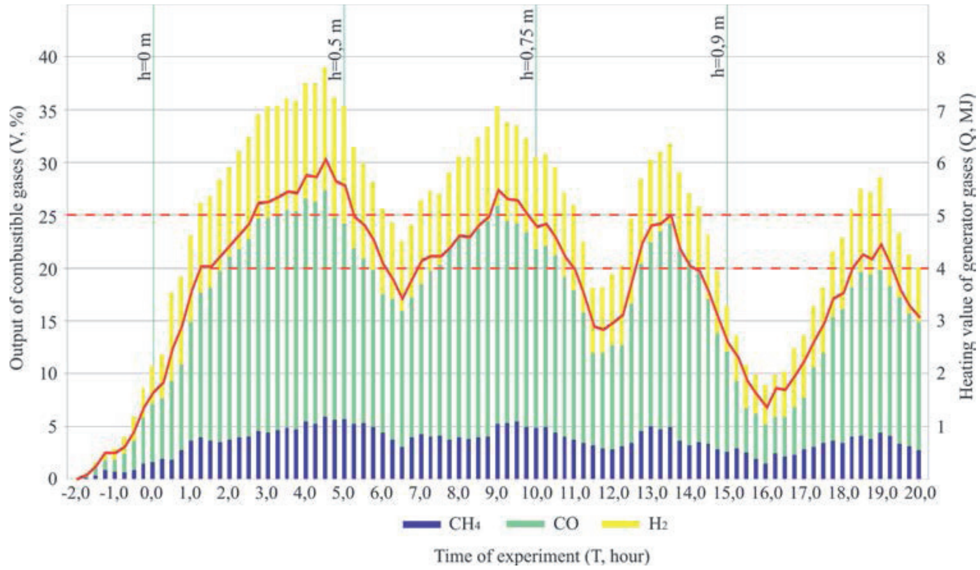

Fig. 2. The total output of combustible generator gases and their heating value during the experiment

It should be noted that the process of gasification is effective, and it is in a stable mode under the condition of the total output of combustible gases more than 25% or its heating value more than 4 MJ/m³.

As the percentage volume fixation of generator gases occurred at the intervals of 15 minutes, in this case, for a more precise definition of the moment when gasification process reaches the regime of stabilization, it is necessary to take into account the total output of combustible gases $\overline{t_V}$, which can be found by the following formula

$$\overline{t_V} = \left[t_1 + \left(\frac{t_2 - t_1}{100}\right) \cdot \frac{25 - \sum C, at\ t_1}{\sum C, at\ t_2 - \sum C, at\ t_1} \cdot 100\right] - t ,$$

where t_1 – the nearest fixed time with the total value of output combustible generator gases $\leq 25\%$; t_2 – the nearest fixed time, with the total value of output combustible generator gases $\geq 25\%$; $\sum C$ – the total percentage content of combustible generator gases; t_3 – the estimated time of crossing the fault plane of disjunctive geological fault.

The next phase of experimental data analysis was to determine the actual time when the gasification process reaches the regime of stabilization. To make this determination we had do include an important parameter, such as heating value $\overline{t_Q}$ that was obtained by the following formula

$$\overline{t_Q} = \left[t_1 + \left(\frac{t_2 - t_1}{100}\right) \cdot \frac{4 - Q, at\ t_1}{Q, at\ t_2 - Q, at\ t_1} \cdot 100\right] - t_3 ,$$

where t_1 – the nearest fixed time with the heating value of combustible generator gases ≤ 4 MJ/m³; t_2 – the nearest fixed time with the heating value of combustible generator gases ≥ 4 MJ/m³.

The heating value of generator gases $Q_{g.g}$ is equal to the heating value of all combustible gases: CO, H_2, CH_4. To determine the heating value of generator gases we can use the next formula

$$Q_{g.g} = \frac{127{,}7 \cdot CO + 108 \cdot H_2 + 356 \cdot CH_4}{1000},$$

where CO, H_2, CH_4 – the percentage of the corresponding generator gases.

Table 1 shows basic parameters, which took place for the calculation $\overline{t_V}$ and $\overline{t_Q}$ for the displacement amplitude considered at a specified time. Due to the experimental studies conducted with the account of the coefficient of geometric similarity, the transfer results in natural conditions should execute the inverse problem, the essence of which is described below.

With the design speed of face combustion $V_g = 9$ cm/hour, which most probably was maintained (as we can see from the results of the study), the coal seam ($l^m_{g.g} = 180$ cm) gasified within 20 hours.

Taking into account the fact that this model corresponds to the length of the gasifier of $l^n_{g.g} = 36$ m, then the time of gasification of extraction pillar will make $t_y = 400$ hours at a similar rate of combustible face advance.

To make the analysis of experimental studies easier we can make the calculation of coal gasification advance to compare the time of gasification in gasifier model t_x and in gasifier in nature t_y and t_z.

Here are the temporal and geometric transformations in the system of equations

$$\begin{cases} l^m_{g.g} \to t_x, \ at\ V_1 \\ l^n_{g.g} \to t_y = \dfrac{l^n_{g.g}}{V_1}, \ at\ V_1 \\ l^n_{g.g} \to t_z, \ at\ V_2 \end{cases},$$

where $t_z = t_x \cdot \dfrac{day}{hour}$, then $V_2 = \dfrac{l^n_{g.g}}{t_z}$.

Table 1

Basic parameters and calculation results $\overline{t_V}$ and $\overline{t_Q}$

Displacement amplitude, m	Time, hour		Gas production, %				Heating value of generator gases, MJ/m^3	The regime of stabilization of underground gasifier, hour	
h			H_2	CH_4	CO	$\sum C$	$Q_{g.g}$	$\overline{t_V}$	$\overline{t_Q}$
0m	t_1	1.00	8.2	3.6	11.3	23.1	3.61	1.09	1.13
	t_2	1.25	8.5	3.9	13.8	26.2	4.07		
0.5m	t_1	6.75	6.9	3.9	13.3	24.1	3.83	1.67	1.72
	t_2	7.00	7.9	4.2	14.3	26.4	4.17		
0.75m	t_1	12.50	8.1	3.4	13.2	24.7	3.77	2.31	2.20
	t_2	12.75	8.1	4.5	15.9	28.5	4.51		
0.9m	t_1	18.00	6.8	3.4	12.7	22.9	3.57	3.07	3.14
	t_2	18.25	7.3	4.0	14.2	25.5	4.03		

In this system of equations temporal and geometric frames are calculated from variables to enable the comparison of numerical values x and z. After the calculation, we obtain the speed of combustion face advance in nature 7.5 cm/hour, and the total time of coal seam gasification $t_z = 20$ days.

The conclusion concerning nature and model similarity enables the calculation of homochronicity criterion, i.e. of constant temporal similarities in the processes. In addition, the invariant and the simplex of similarity in thermochemical processes were considered.

Now we can get the dependence of the fault plane amplitude on the distance at which the underground experimental gasifier reaches the regime of stabilization based on generator gases production and heating value of generator gases (fig. 3).

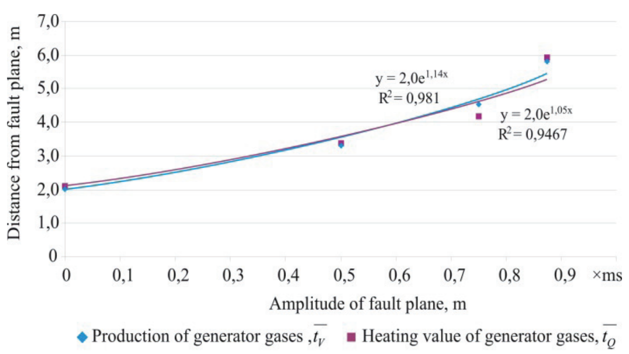

Fig. 3. The dependence of the fault plane amplitude on the distance at which the gasifier reaches the regime of stabilization

Fig. 3 shows how the hourly value, when underground coal gasification reaches the regime of stabilization, was comprised with the distance from the fault plane by the following simplification

$$l^m_{g.g} \to t_x = l^n_{g.g} \to t_z \quad \Leftrightarrow \quad t_x = t_z.$$

Accordingly $l_{\overline{t_V}} = \frac{l^n_{g.g}}{t_z} \cdot \overline{t_V}$ and $l_{\overline{t_Q}} = \frac{l^n_{g.g}}{t_z} \cdot \overline{t_Q}$.

Fine precision of the received results (fig. 3) allows us to determine the distance from fault plane at which the gasification process reaches the regime of stabilization.

$$l = 1{,}9e^{1{,}1 \cdot h_{d.a}},$$

where $h_{d.a}$ – the displacement amplitude of the fault.

It is undoubted that the time of passing some distance by underground gasifier can be corrected by speed advance of the combustion face. Thus, the rate of gasification enhancement characterizes the change in speed advance of a combustion face (fig. 4). Speed advance depends on the balanced quantity of the injected air.

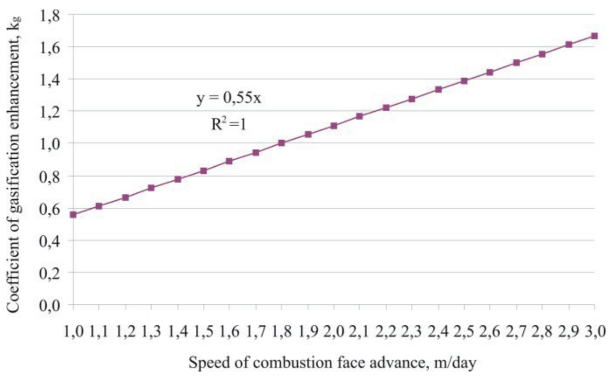

Fig. 4. Change dependency of coefficient of gasification enhancement $k_в$ in accordance to the speed advance of combustion face

After the enhancement of the coal seam gasification, we have an opportunity for a shorter time reach the regime of stabilization; however, these actions require additional technical implementations in the gasifier operation.

Research conclusions and recommendations for further research in this area.

1. The reduce of the percentage concentration of combustible generator gases appears ahead of disjunctive fault plane of a geological fault, because of the breakdown of the chemical zone in the coal seam perpendicular to the reaction channel.

2. Time t at which underground gasifier reaches the regime of stabilization, that is determined by the total output of generator gases and the heating value of generator gases crossing disjunctive geologic fault with the amplitude up to 0.9 of coal seam thickness at an exponential dependence de-pends on the displacement amplitude $h_{d.a}$ and the speed of combustion face advance V_g.

3. The enhancement of the geological fault crossing zones depend on balanced supply of injected reagents, respectively, taking into account heterogenic geometry of coal seam, it is necessary to conduct additional calculation of material and heat balance and make manual mode of gasification process.

4. It will be effective to conduct similar studies using computer simulation to confirm or refute the results of experimental studies on laboratory unit in the further researches. In addition, it is necessary to conducta detailed study of coal seams abandon after the mining, where traditional mining is inefficient.

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Мета. Обґрунтування можливості переходу диз'юнктивних геологічних порушень без розриву суцільності вугільного пласта підземним газогенератором, виходячи із встановлених залежностей зміни часу виходу підземного газогенератора на ефективний режим вигазовування при застосуванні технології свердловинної підземної газифікації вугілля.

Методика. Стендовими експериментальними дослідженнями встановлені залежності зміни часу виходу підземного газогенератора на ефективний режим вигазовування при підземній газифікації вугілля.

Результати. Отримані залежності впливу амплітуди зміщувача геологічного порушення на відстань, за якої газогенератор переходить на ефективний режим вигазовування за сумарним виходом горючих генераторних газів та їх теплоти згорання. Представлена залежність зміни коефіцієнта інтенсифікації вигазовування, що залежить від кінетики протікання термохімічних реакцій у реакційному каналі підземного газогенератора. Запропонований підхід для перенесення результатів стендових експериментальних досліджень до натурних умов на основі геометричнихта часових спрощень. Результати досліджень дадуть змогу внести корективи в розрахунок матеріально-теплового балансу процесу газифікації для визначення оптимального якісного та кількісного складу дуттьової суміші.

Наукова новизна. Час виходу підземного газогенератора на ефективний режим вигазовування визначається ступенем нерозривності вугільного пласта та регулюється швидкістю посування вогневого вибою та збалансованою подачею реагентів дуття.

Практична значимість. Отримані результати стендових експериментальних досліджень з достатньою для практичного застосування точністю можуть використовуватися для визначення параметрів виходу підземного газогенератора на ефективний режим вигазовування, 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 енергетичного та хімічного генераторного газу, хімічних продуктів та теплової енергії.

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

Цель. Обоснование возможности перехода дизъюнктивных геологическихнарушений без разрыва сплошности угольного пласта подземным газогенератором, исходя из установленныхзависимостей изменения времени выхода подземного газогенератора на эффективный режим выгазовывания при применении технологии скважинной подземной газификации угля.

Методика. Стендовыми экспериментальными исследованиями установлены зависимости изменения времени выхода подземного газогенератора на эффективный режим выгазовывания при подземной газификации угля.

Результаты. Получены зависимости влияния амплитуды сместителя геологического нарушения на рас-

стояние, при котором газогенератор переходит на эффективный режим выгазовывания по суммарному выходу горючих генераторных газов и их теплоты сгорания. Представлена зависимость изменения коэффициента интенсификации выгазовывания, который зависит от кинетики протекания термохимических реакций в реакционном канале подземного газогенератора. Предложен подход к переносу результатов стендовых экспериментальных исследований в натурные условия на основе геометрических и временных упрощений. Результаты исследований позволят внести коррективы в расчет материально-теплового баланса процесса газификации для определения оптимального качественного и количественного состава дутьевой смеси.

Научная новизна. Время выхода подземного газогенератора на эффективный режим выгазовывания определяется степенью неразрывности пласта и регулируется скоростью подвигания огневого забоя и сбалансированной подачей реагентов дутья.

Практическая значимость. Полученные результаты стендовых экспериментальных исследований, с достаточной для практического применения точностью, могут использоваться для определения параметров выхода подземного газогенератора на эффективный режим выгазовывання, дают возможность расширить область применения технологии скважинной подземной газификации угля в зонах геологического нарушения горного массива и, в перспективе, привлекать к отработке некондиционные залежи каменного угля для получения энергетического и химического генераторного газа, химических продуктов и тепловой энергии.

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

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НОВІ КОМПОЗИТНІ МАТЕРІАЛИ КРІПЛЕННЯ ГІРНИЧОЇ ВИРОБКИ

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THE NEW COMPOSITE DESIGNS FOR MINE TUNNEL SUPPORT

Мета. Створити новий спосіб кріплення гірничої виробки з використанням ефективних та надійних конструкцій. Розробити конструктивні та проектні рішення. Обґрунтувати ефективність та доцільність використання створених кріплень гірських порід у підземних виробках при освоєнні родовищ.

Методика. Виконаний комплекс теоретичних, аналітичних і експериментальних досліджень. Проведений аналіз існуючих конструкцій кріплень гірничих виробок з виділенням їх недоліків та переваг. Із матеріалів з фізико-механічними характеристиками, еквівалентними реальним конструкціям, ураховуючи теорію подібності, виготовлені моделі експериментальних зразків та проведені лабораторні випробування. Виконане моделювання та чисельні розрахунки з використанням методу скінченних елементів.

Результати. Теоретично та експериментально підтверджена доцільність застосування композитних матеріалів при зведенні конструкцій кріплень гірничих виробок, сформульовані основні принципи їх проектування й виготовлення. На підставі отриманих результатів запропонована просторова площинно-стрижнева система кріплень, що забезпечує високу несучу здатність та надійність. Розроблені системи кріплень складаються із просторової структурної решітки та плити. Математичним моделюванням визначені ефективні способи об'єднання решітки й плити та необхідні фізико-механічні характеристики матеріалів.

Ураховуючи конструктивні особливості системи кріплень, розроблена технологія виконання робіт з її влаштування. Наведена технологія виготовлення відправних елементів. Розрахована трудомісткість виконання робіт. Підтверджена економічність запропонованого способу зведення кріплень.

Наукова новизна. Розроблений новий спосіб кріплення гірничих виробок із застосуванням просторових композитних конструкцій.

Практична значимість. Розроблена конструкція може використовуватися в гірничій промисловості в сучасних економічних умовах. Дозволяє знизити тривалість та трудомісткість робіт.

Ключові слова: *сталезалізобетон, структура, решітка, стрижень, кріплення, гірнича виробка*

Постановка проблеми в загальному вигляді та її зв'язок із важливими практичними завданнями. Гірнича виробка – штучне утворення в земній корі порожнин шляхом виїмки гірських порід. Для цього утворюються шахтні стовбури, штольні, квершлаги, горизонтальні та похилі виробки. Для проходження гірничих виробок, залежно від їх призначення, гірничо-геологічних та гідрологічних умов, існує декілька способів. Способи проходження гірничих виробок залежать також від рівня й ступеня механізації гірничопрохід-