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DEVELOPMENT OF A LABORATORY UNIT AND A SOLID FUEL GASIFICATION REACTOR

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РОЗРОБКА ЛАБОРАТОРНОЇ УСТАНОВКИ ТА РЕАКТОРУ ГАЗИФІКАЦІЇ ТВЕРДОГО ПАЛИВА

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The paper investigates the process of gasification of pyrolysis coal and other coal-containing materials
A schematic diagram of the installation of the gasification process of pyrolysis coal and other coal-containing materials was developed, the design of the reactor for coal gasification and the methodology for conducting experiments and analysing the gasification process of pyrolysis coal and other coal-containing materials were developed. Research methods - modelling of the coal gasification process using the results of theoretical studies.
A detailed analysis of the experimental and theoretical data concerning the feasibility of the pyrolysis coal gasification process was carried out, a schematic diagram of the laboratory installation and the design of the gasification reactor were developed.
The main goal is to develop a method of gasification of solid pulverised fuel that will simplify the process control and ensure its stability due to the unity of the drying and gasification processes of pyrolysis coal, which are linked by means of a gasification reactor. Additionally, this method provides for the neutralisation of harmful impurities generated during the coal gasification process.
As a result of theoretical studies of the solid fuel gasification process, a design of a coal gasification reactor was proposed, which is an ideal displacement reactor. The length-diameter ratio for the working part of the reactor should be at least 10:1. It is proposed to use a heat-resistant molybdenum steel tube (operating temperature up to 1600 0C) with a diameter of two inches to manufacture the reactor. Also, to study the gasification process of pyrolysis coal and other coal-containing materials, a laboratory installation for gasification of solid crushed fuel is proposed, in which a gas mixture of carbon dioxide and oxygen is fed into the reactor and serves as an activator of the gasification process. The prospects of coal processing by gasification to produce a mixture of combustible gases (H2, CO, CH4) are investigated. It is analysed that coal gasification allows obtaining valuable gas that can be used not only as an energy fuel, but also as a technological raw material for the production of methanol, dimethyl ether, hydrogen production, and use as a reducing agent in metallurgical processes.
Keywords: *pyrolysis coal, gasification, combustible gases, gas mixture, carbon dioxide,* oxygen, gasification reactor.

Introduction. Due to the difficulties in supplying Ukraine with oil and gas, there is a growing interest in the use of unconventional energy sources such as wind, solar and biogas. However, coal gasification can fundamentally solve the problem of the country's energy supply. Ukraine has sufficient long-term coal reserves, including lignite. The current practice of using lignite in Ukraine is irrational, as it involves direct combustion at thermal power plants, which worsens the environment and causes emissions of dust, carbon dioxide and sulphur.

In global practice, lignite is processed using new efficient technologies to produce combustible gases, liquid fuels, fertilisers and other products for various industries and agriculture.

The raw material resource of coal can be used to the fullest extent when it is processed in an integrated manner. Gasification is an important part of integrated coal processing. There are a large

number of methods of thermal treatment of solid fuels, but gasification is one of the most promising.

Coal gasification is one of the oldest industrial technologies. The first mention of producing combustible gas from charcoal dates back to 1609, when John Van Helmont of Brussels made a report on the subject. The first commercial implementation of solid fuel gasification took place in 1835 in the UK. However, with the advent of significant oil, natural and associated gas production, the production of gas from coal has declined significantly. However, in the future, solid fuel gasification may take an important place among the methods of processing coal into chemicals and motor fuels.

The problem of providing the population with sufficient gas plays an important role in social life. It can be avoided or solved by coal gasification, a method that is gaining popularity in various countries. The essence of this process is the conversion of coal into gas, which allows for the extraction of coal mine methane, also known as coal bed methane. The use of this gas contributes to the efficient and rational use of natural resources.

Outline of the main material.

Coal gasification is the process of converting a coal product into a gaseous substance through incomplete oxidation at high temperature and different pressures. Coal is converted to gas by using a controlled thermochemical process in a heat wave mode.

Coal gasification means its conversion with the help of gasifying agents oxygen and water vapour in a mixture of combustible gases (CH4, H2, CO). Depending on the composition, ratio of the initial substances, temperature, and duration of interaction, gas mixtures of different composition can be obtained [1-3]. Stationary bed gasification is the oldest method of gasification. It is carried out in a cylindrical shaft (reactor). In this case, fuel is fed from above, and the gasifying agent is fed from below. Gasification takes place at temperatures above 1000 °C. Gasification using air produces a low-calorific gas (Qv=5.2 kJ/mol) with the following composition (% vol.): CO - 27.8; H2 - 12.4; CO2 - 3.6; SN4 - 0.2; N2 - 56. Gasification with water vapour produces a combustible gas containing mainly more than 40 % vol. CO and 50 % vol. H2. Coal gasification under pressure of oxygen and water vapour produces a higher methane yield and a higher calorific value of gas. For all types of coal, increasing pressure promotes methane formation, while carbon dioxide and hydrogen production decrease. Fluidised bed gasification is the gasification of fine coal. The crushed coal is fed by a screw into a gas generator. Ash with a melting point higher than the gasification temperature is discharged from the bottom. The resulting synthesis gas is re-gasified in the upper part of the gas generator and then treated in a condenser refrigerator. The heating value of the synthesis gas reaches 12300 kJ/m3. The advantages of this method are determined by the less stringent requirements for coal grain size. Gasification of pulverised coal is carried out by direct flow at atmospheric pressure. The pulverised coal is fed by a nitrogen stream into the gas generator's feed hopper. It is mixed with oxygen and water vapour on the screw and enters the reaction chamber. The gasification temperature is 1500-1600 °C. This achieves a high degree of carbon conversion. This method is used to produce synthesis gas for ammonia production. The approximate composition of this gas (% vol.): CO - 57; N2 - 31; CO2 - 10.5; SN4 - 0.1; N2 - 1.2; N2S - 0.3. The calorific value of gas is Qc = 11.2 kJ/kg. One of the gasification methods is underground coal gasification, which involves drilling vertical and horizontal wells and gasification channels. Gasifying gas is injected into one well and synthesis gas comes out of the other. Underground coal gasification is a technology for converting fuel into combustible gas directly at the place of its occurrence.

As a result of the study, a method of gasification of pyrolysis coal was proposed, which uses a combination of coal drying and gasification processes, carried out using a coal gasification reactor, which is an ideal displacement reactor. This ensures easy process control and sustainability. In addition, hazardous emissions generated during fuel gasification can be effectively neutralised in the reactor. Thus, the development of a gasification method is aimed at improving the efficiency and reliability of the coal gasification process, which makes it a relevant research topic.

The aim of this work is to develop a pyrolysis coal gasification unit, in which the unity of coal drying and gasification processes linked in a common idealised displacement reactor ensures ease of process control and its stability. To achieve this goal, the following main research objectives have been defined:

Analysing the theoretical aspects of the process of thermal conversion of pulverised coal into gaseous fuel allowed us to develop a gasification unit for solid pulverised fuel.

The novelty of the obtained results lies in the creation of a method for gasification of pulverised coal, which involves preliminary drying and

gasification of pyrolysis coal using a gas mixture, carbon dioxide and oxygen.

The practical significance of the obtained results is that the developed gasification method can be used in power plants for the production of heat and electricity. fuels, in particular phenols, sulphur dioxide, etc.

Thanks to the theoretical studies, taking into account the previous shortcomings, the design of the coal (pyrocarbon) gasification reactor was proposed (Fig. 1).

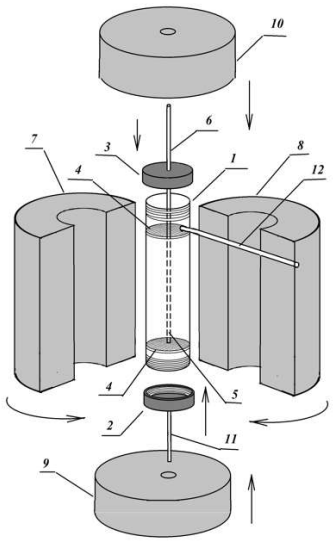

Fig. 1. Coal gasification reactor

The coal gasification reactor is a perfect displacement reactor. The length-to-diameter ratio for the reactor working part should be at least 10:1. It is proposed to use a heat-resistant tube made of molybdenum steel (operating temperature up to 1600 0C) with a diameter of two inches for the reactor.

The reactor consists of a vessel 1, which is closed at the bottom and top by a threaded connection with covers 2 and 3. The working area of the reactor is limited by two sieves 4, which are installed on the top and bottom of the reactor 1. In the middle of the reactor there is a stationary part of the thermal pocket 5. The movable part of the thermowell 6 is welded to the top cover of the reactor 3 and is connected to the fixed part when the reactor is closed. The fitting 11 for the gas mixture inlet to the reactor is welded into the bottom cover of the reactor 2. The fitting 12 for the gas mixture outlet from the reactor is welded into the upper part of the vessel 1 above the upper sieve 4.

The reactor is thermally insulated from the outside. Thermal insulation is made of solid thermal insulation material. The thermal insulation casing consists of four parts: side parts 7 and 8, which, when closed, form a cylinder, and two thermal insulation covers 9 and 10, which are equipped with holes.

Diagram of the laboratory installation for studying the coal gasification process.

The following setup is proposed to study the gasification process of pyrolysis coal and other coal-containing materials(fig. 2).

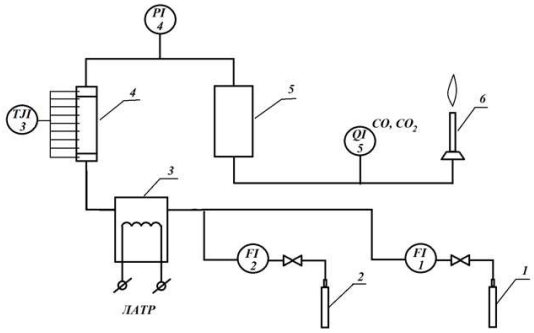

Fig. 2. Laboratory installation for studying the gasification process of pyrolysis coal and other coal-containing materials

The pyrolysis coal is loaded into the gasification reactor 4. The gas mixture of carbon dioxide CO2 and oxygen O2 at a given oxygen concentration is prepared from cylinders 1 and 2 using valves according to the readings of rotameters FI-1 and FI-2. The gas mixture with a given oxygen concentration is heated, if necessary, to a given temperature in the heater 3 using an electric heating element. The power of the electric heating element is regulated by the LATR. The gas mixture of carbon dioxide and oxygen is fed into the reactor 4 from below. In the reactor, the pyrocarbon gasification process takes place. The temperature along the height of the reactor is measured using a multi-zone thermocouple, and the readings are displayed on a secondary device TjI-3. The pressure at the reactor outlet is measured with a pressure gauge PI-4. The pressure drop between the reactor inlet and outlet is also measured.

From the reactor 4, the gas mixture enters the field apparatus 5, which serves as a heat exchanger. From the heat exchanger 5, the gas is fed to the QI-5 gas analyser, which measures the concentration of oxygen, carbon monoxide and carbon dioxide and then is fed to the flare unit 6. A bubbler (Drexel glass) is installed in front of the flare for visual control of the process.

Conclusion The prospects of coal processing by gasification to produce a mixture of combustible gases (H2, CO, CH4) have been investigated. It was analysed that coal gasification allows to obtain valuable gas that can be used not only as an energy fuel, but also as a technological raw material for the

production of methanol, dimethyl ether, hydrogen production, and use as a reducing agent in metallurgical processes.

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Слободянюк В.П., Шлапак С.О., Целіщев О.Б., Кудрявцев С.О., Лорія М.Г., Дурищев О.А. Розробка лабораторної установки та реактору газифікації твердого палива.

В роботі досліджено процес газифікації піролізного вугілля та інших вуглевмісних матеріалів

Розроблено принципову схему установки процесу газифікації піролізного вугілля та інших вуглевмісних матеріалів, розроблено конструкцію реактору для газифікації вугілля та методику проведення експерименту та аналізу процесу газифікації піролізного вугілля та інших вуглевмісних матеріалів. Методи дослідження - моделювання процесу газифікації вугілля з використанням результатів теоретичних досліджень.

Було проведено детальний аналіз експериментальних та теоретичних даних, що стосуються можливості здійснення процесу газифікації піролізного вугілля, була розроблена принципова схема лабораторної установки та конструкція реактора газифікації.

Основна мета полягає у розробці методу газифікації твердого подрібненого палива, що забезпечить спрощення управління процесом та його стійкість завдяки єдності процесів підсушуванні, і газифікації піролізного вугілля, які пов'язані за допомогою реактору газифікації. Додатково, цей метод передбачає нейтралізацію шкідливих домішок речовин, які утворюються під час процесів газифікації вугілля.

В результаті теоретичних досліджень процесу газифікації твердого палива було запропоновано конструкцію реактору газифікації вугілля, який являє собою реактор ідеального витиснення. Співвідношення довжина-діаметр для робочої частини реактора має бути не меншим ніж 10:1. Пропонується для виготовлення реактора використати жаростійку трубку з молібденової сталі (робоча температура до 1600 ^{0}C) діаметром два дюйми. Також для дослідження процесу газифікації піролізного вугілля та інших вуглевмісних матеріалів запропоновано лабораторну установку газифікації твердого подрібненого палива в якої газова суміш діоксиду вуглецю та кисню подається в реактор та є активатором процесу газифікації. Досліджено перспективи переробки вугілля методом газифікації для одержання суміші горючих газів (H2, CO, CH4). Проаналізовано, що газифікація вугілля дозволяє отримувати цінний газ, який можна використовувати не лише як енергетичне паливо, а й технологічну сировину для виробництва метанолу, диметилового ефіру, одержання водню, використання в якості відновника в металургійних процесах.

Ключові слова: *піролізне вугілля, газифікація, горючі гази, газова суміш, діоксид вуглецю, кисень, реактор газифікації.*

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