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Application of thermal methods to increase the efficiency of coalbed methane production

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Abstract

In recent years, the expansion of the base of energy raw materials occurs through the involvement of new unconventional sources into operation. The development of new technologies made it possible to extract methane and its homologues from sedimentary formations that were not previously considered as sources of natural gas. One of these formations are coal-bearing strata. In some cases, the development of coal seams using traditional methods (quarry and mine) is impossible due to mining, geological, economic, technical and other reasons. The volume of industrial production of coalbed methane in foreign countries is beginning to have a significant impact on global gas markets. Industrial extraction of methane is conducted in the USA, China, Canada and other industrialized countries. It should be noted that the potential of unconventional resources of methane is huge - the resources of coal in the world reach 15 trillion tons. Coals are a promising source of coalbed methane. Gas output can be increased by thermal exposure to the coal seam. We have carried out studies of residual gas components from samples of fossil coal by the method of combined thermogravimetry (TG) and IR spectroscopy (IR). The method of thermogravimetry allows us to estimate the amount of gas sorbed in the coals, and IR spectroscopy to identify the composition of the emitted gases in each temperature range. Data on the composition of gas fractions in various temperature ranges was obtained.

1. Introduction

The expansion of the base of energy raw materials occurs due to the involvement of new sources of hydrocarbons in the operation, one of them is coal seams gases. Fossil coals are high-gas-capacity rocks. They have a great resource potential of coalbed methane. It should be noted that the potential of unconventional methane resources is huge. The world's coal resources in sediment exceed the amount of any other energy carriers. Coals can be a practically inexhaustible source of coalbed methane. Currently, industrial production of coalbed methane is growing in the world, which is beginning to have a significant impact on gas markets. The largest amounts of coalbed methane are mined in the United States, China and Canada [1,2]. In Russia, the extraction of methane from coal seams is carried out at the pilot site by the company Gazprom Mining Kuznetsk [3]. Natural gas is one of the most



environmentally friendly types of hydrocarbons. The development of coal seams is carried out using inclined drilling technologies. Produced gas is an analogue of natural gas. It is used for domestic needs and for the working of local power plants. Significant untapped coal resources are associated with the Volga-Ural oil and gas province, where coal-bearing strata are distributed in Tatarstan, Udmurtia and Bashkortostan. Oil reserves here are greatly depleted as a result of years of development. In this regard, in the future, coal-bearing strata of the region can be considered as a promising source of hydrocarbon raw materials. To date, only in Tatarstan their total resources exceed 3.5 billion tons [4, 5, 6]. In total, 95 deposits were identified and assessed in Tatarstan, which in their scale correspond to small and medium-sized deposits. The coal seams are confined to the fill-in section of the Visean terrigenous formation. The thickness of coal deposits varies from 1 to 30 m. In terms of scale, they all belong to small and medium-sized deposits with resources ranging from the first to several hundred million tons. The main structural forms to which the most powerful coal seam is confined are erosion-karst downcuts. The contours of the coal deposits are controlled by the boundaries of the downcuts. The coal seam thickness reaches 10-29 m. The Visean coals have the following quality parameters: ash content - 15-26%, volatile matter yield - 41- 48%, sulfur content - 3.1- 4.2%, heat of combustion 29.9- 31.4 MJ / kg, content of toxic elements low. The mining and geological conditions of the Visean coal deposits are extremely complex, due to the deep occurrence of coal seams (about 900-1400 m), unfavorable groundwater regime, gas content and poor stability of coal-bearing rocks. Currently, coal deposits are not being developed, but they can be used as a source of coalbed methane. Gas output from coal seams is significantly lower than in natural gas fields. However, it can be increased as a result of thermal effects on the coal seam, which can be carried out through wells.

2. Methodology

Hard coal and brown coal from Visean coal beds in the territory of the Volga-Ural oil and gas province was used as the samples under study. By nature, the Visean coals are humits. By the degree of metamorphism, the Visean coals are mostly hard, sometimes brown. The degree of metamorphic transformation have great importance for the gas content of coal and for the composition of hydrocarbon gases sorbed in the coal. In the present work, a study was made of the composition of the gas components of coal and the characteristics of their release during heating. For this, the combined thermogravimetry (TG) and IR spectroscopy (IR) method was used. The thermogravimetric experiment was described in detail in previous works [7, 8]. The method of thermogravimetry allows to estimate the amount of gas sorbed in the coals. Using IR-spectroscopy is determined by the composition of the evolved gases in each temperature range. The analysis was performed on a TG 209 F1 Libra (Netzsch) thermogravimeter combined with an Alpha FTIR-spectrometer (gas cell) (Bruker Inc.). The measurements were carried out in a dynamic stream of nitrogen at a purge rate of 75 ml / min in the temperature range from room temperature of 30 ° C to 800 ° C in open corundum (45 µl) crucibles at a heating rate of 20 K / min. The temperature of the transit line to the spectrometer was 250 ° C, the temperature of the optical part of the spectrometer — 200 ° C. To analyze the composition of exhaust gases during thermal exposure (EGA or Evolved Gas Analysis), the IR absorption spectrum was taken in the range of wave numbers from 4000 cm⁻¹ to 400 cm⁻¹. Gas purity was improved to 99.99999% and water vapor was removed using a Click-On filter (SGT-A-flow Moisture trap). The device was calibrated by temperature according to 9 melting points of high-purity metals (Bi, In, Sn, Bi, Pb, Zn, Al, Ag, Au).

Samples of coal were weighed on a Sartorius precision scale with an internal calibration function.

3. Results and Discussions

The existing technology for producing methane from coal seams and coal-bearing strata is based on drilling wells (vertical, inclined or horizontal) in the coal deposit (field) and destruction of the coal seam using the hydraulic fracturing method. As a result, additional coal degassing occurs. Excess gas in the free or dissolved state in water is brought to the surface through wells and after a certain cleaning can be used for its intended purpose. The experience of the methane-coal field in Kuzbass showed [3] that the volume of gas production depends mainly on the filtration parameters of coal seams (porosity) and structural and geodynamic features of the rock mass, and not on the thickness of the coal seams and their total methane content. Visean coals occur at a depth of about 900-1400 meters, where high pressure and temperature prevail. Under these conditions, gas, coal and water in the coal seam are in a complex interaction. Unlike traditional deposits of natural gas, where natural gas is concentrated in the hollow-pore space of reservoir rocks [9], coal seams with sorbed methane are complex natural systems. They consist of organic matter of coal, sorbed in the coal substance of gas, gas-saturated waters and natural cracks in the coal. In coal, methane is present as free gas, sorbed gas and solid solution [10]. Up to 75% of methane in coal is present in adsorbed form [11], where its amounts are adsorbed on the surface of coal particles. At the considered depths, the main amount of methane is in the sorbed state. With increasing pressure, the amount of sorbed methane in coal increases, and decreases with increasing temperature. With the existing technologies of hydraulic fracturing extracting that part of the gas, which is in the pores and adsorbed on the surface of coal particles. This gas is easily removed from the coal. The remaining quantities of methane are associated with the substance of coal and can be extracted as a result of the process of its destruction. The most effective way to destroy the structure of a coal substance is thermal exposure, which leads to the removal of gaseous components. As shown in [12], during thermal exposure, volatile components are released, their proportion reaching 30–40 wt. %. The coals studied are hard, sometimes brown [13]. Hard coal has the greatest gas content. Our studies of Visean coals by the method of thermogravimetry (TG) and IR spectroscopy (IR) allow us to estimate the amount and composition of the gas sorbed in the coals. The test samples were subsequently heated to 800 °C with the determination of the weight loss resulting from the release of gaseous components.

The release of gaseous components occurs in several intervals, each of which is characterized by its composition of gases. At the first stage, in the temperature range from room temperature to 150 °C, the adsorbed water evaporates. Then, in the temperature range from 250-270 °C to 500-550 °C, a pyrolysis zone of polycyclic aromatic structures is observed, which is accompanied by the release of methane and some cyclic methyl-substituted cycloalkanes. At the final stage, in the temperature range of 550-800 °C, a pyrolysis zone of higher thermostable cyclic compounds is observed. This zone is characterized by the release of partially heavy hydrocarbon gases and further by simplifying the composition of the gas components until the organic matter is completely burned out.

4. Conclusions

As a result of the research, it was established that during the pyrolysis of polycyclic aromatic structures with the release of the main mass of methane occurs in the temperature range from 250 to 550 ° C. Further heating of the sample to 800 ° C leads to the release of heavy hydrocarbon gases and up to the complete burning out of organic matter. Thus, the use of modern technologies for the development of "shale gas" in combination with thermal methods will increase the volume of gas extracted from coal seams. The obtained results can be useful for choosing the temperature regime of impact on the coal seam during its development.

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