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NOVEL TECHNIQUES RELATED WITH COAL MINING

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ABSTRACT: Complex methods of geotechnical, physical-chemical and biological treatment of coal are discussed. Underground coal gasification / combustion in situ combined with coal bed methane drainage from coal mass and physical-chemical-microbiological coal mass treatment is considered as one of the most ecologically clean and resource saving technologies. A new approach to coal electricity generation on the basis of borehole coal mining (coal gasification /combustion in situ) with coal bed methane drainage integrated with mine mouth combined cycle thermopower plant is promoted.

1. INTRODUCTION

Conventional technologies of coal mining, benefeciation and utilization in power generation are characterized with a rather low economic and ecological efficiencies.

The unconventional, so called, shaftless technologies of coal and coal bed methane extraction through boreholes drilled from the surface with physical-chemical -biological coal mass treatment provide resource saving and ecologically clean methods of coal-methane deposit exploitation.

In general a term "unconventional coal mining" or "non-traditional mining technology" is getting more and more familiar to the mining engineering media. Here is the methods of shaftless or the more specifically termed borehole mining are understood. Now a general opinion is widely spread that an application of traditional /conventional technologies of coal mining and electric power generation would inevitably cause further irreversible damage of the global eco-system. Keeping the recent pace of the eco-system degradation the whole of our civilization would be in danger. Thus the solution of this problem is to be found in developing, promoting and implementing unconventional coal mining and modern advanced clean coal technologies.

One of the greatest potential for coal resource utilization during the beginning decades of oncoming century is the synthetic fuel gas derived from coal as a product of coal gasification whether in situ or in surface plants. It is quite logical to enrich this gas prior to combustion with coalbed methane, contained in coal measures. Proposed unconventional technology of coal mining is characterized with: - opening up a coal deposit through boreholes, drilled from the surface and used for coalbed methane drainage as well as for coal gasification/combustion in situ. Thus here we have an aggregation of methane producing and coal gasification facilities on mining side with thermopower plant on electric power generation side in one integrated industrial complex unit or enterprise.

The further improvements of the conventional coal mining technologies both the surface and underground could provide only insignificant results in economical, ecological and social aspects, but would not be able to meet the basic requirements of the oncoming century. Significant and dramatic increase in economic efficiency, cardinal humanization of coal mining and basic improvements in environment protection would be achieved through implementation of innovative or unconventional technologies.

Because of high labour-intensiveness and costs of coal mining as well as a high risk of underground labor and ecological damage of environment new way of mining improvement must be found and in particular methods of borehole mining. The methods may be realized after development process of coal mass only or loss of coal mass stability. This process is named as destruction or *disintegration* of the one else what it is needs for coal transformation in transportable forms: gassy and liqiud or broken up conditions. Physical and chemical as well as microbiological methods are more realized in this time. The method of forming a liquid-product from a coal mass isn't discussed here.

Besides supporting technological advances as: physical-chemical and microbiological treatment of coal mass aiming at methane reduction and desulphurization of the one would help for strengthening of modern unconventional innovative coal mining and utilization technologies.

2. COMPLEX MICROBIOLOGICAL METHODS OF COAL MASS TREATMENT

Historically the first methods of physical and chemical treatment of coal mass were used for coalbed methane extraction from coal measures (Vasyuchkov, 1986). These methods have shown high results for decrease of methane emission as high as 40-60% in mine workings in 11 mines of Karaganda basin (Khazachstan) and in 3 mines of Donetsk basin (Ukraine) and higher effectiveness up to 20-30% as compared with water hydrofracturing method. The methods consist of next processes: drilling of boreholes from the surface to a coal seam and casing of them and treatment of the seam by chemical solutions in regimes of hydrofracturing or filtration. In further the microbiological method was formed from those methods.

2.1. Microbiological sulphur content reduction and désintégration of natural coal.

Microbiological method for sulphur reduction has been suggested by prof. Vasyuchkov in 1991 and developed as a result of joint R&D of "Mineral" Ltd. and Moscow State Mining University and Dnepropetrovsk State University (Vasyuchkov, Kuznetsova, 1993). The first way of development of the method was to increase of quantity of natural coals.

It will be emphasized that to develop of coal mass is increase of natural cracks gaping. In order to confirm this opinion the mineral filing of the cracks would be considered. As a rule besides clay and sandy soils and limestones several sulphur substances have been included into a mineral part of natural coal. Forms of the substances may be different: organic and sulfate and pyrites, etc. For weakening of coal mass the lixiviation process might be used. However the process is not enough effective for organic and sulphate kinds of the suphur substances. And so to use of a microbiolgical method for a coal mass bioleaching is very important. During the method realization a destruction of a coal seam minerals takes place to form mineable coal mass. A growth of a coal mass destruction are considered to provide decrease of mechanical strength of the one.

Sulphur-destruction biocultures can be rather effective as a mean of coal mass désintégration which is the first initial preparatory operation in borehole mining methods. Sulphur content in coal from different coal deposits varies in rather wide range. The highest sulphur content in coal over 6.0% recorded for Kizil coalfield in Ural (Russia). Donetsk coals are characterized with sulphur content as high as up to 3.5% but the sulphur content of Kuznetsk coals doesn't exceed 1.0%.

Field trials conducted in Selidovo region (Ukraine part of Donetsk coal basin) on the coal taked from the seams \\ and ni3 and in Gukovo region (Russian part of the one) on the coal taked from the seam h showed that microbiological coal treatment proved to be very effective since sulphur content was reduced of 11.6-43.6% and the same time lead to coal destruction. The microbiological processes have provided decrease (up to 20-25%) of ash content of coal mass too. Thus microorganisms can effect specially and directory on mineral components of coal mass.

Microbioculture of *Thiobucillus* kind was used with cultural mixture (media) (kg/m^3): 0.5 $(NH_4)_3S0_4$; 0.05 KCL; 0.5 K_2HP0_4; 0.5 $MgS0_4$ • 7H2O; 0.01 (NOs)2. A desirable temperature of prepared biosuspension for the process was of 30-35 C. It was tested microbioculture of *Achromobacter* kind. Fresh air should be delivered with intesity of 3 m^3/hour per $1m^3$ of solution. The biosuspension is given to the coal and matured usually during 3-4 days.

Biological coal treatment is intended to reduce sulphur and ash content in coal. This method stands as an alternative to conventional coal cleaning at coal washeries where ash is removed from coal by mechanical and physical-chemical methods and traditional Flue gas Desulphurization (FGD) technique applied at coal fired power plants.

Thus biological coal treatment demonstrates its efficiency and hence the further developments of the method are very much desirable.

2.2. Borehole method of microbiological oxidation of coalbed methane (CBM) in coal mines.

The method was offered by Moscow State Mining University in 1963. This method may be realized both from the surface and mine workings since work liquid or biosuspension are given through boreholes into a coal seam. In our industrial tests the biosuspension consisted of a mixture from a culture of microorganisms and water solution of salts which made a process of oxidation of coalbed methane and was named as "methane-trofic". These bacteriums have vital functions to consume of methane as food for reproduction and getting of energy and carbon . Now it is known 26 kinds of microorganisms which use methane gas for itself vital functions.

Usual concentrations of methane in air-methane mixtures for oxidation process are 0.5-95.5%. Most active vital functions of methane-trofic organisms carry in neutral liquid media and temperature as high as 28-32 °C. The activiness of the microorganisms is decreased with dropping of a temperature of the process and are standed for 2-4 °C

practically. This fact is very usefull for saving and transportation processes of biosuspension. For active vital functions the several salts are used: NH4CL, Na2HPC>2- I2H2O, MgSOi», etc. The biosuspension must be saturated with oxygen of air. These biocultures may have good vital functions for gas pressure as high as 100 MPa.

The coal mass biotreatments was performed through boreholes drilled from the surface in Karaganda (Khazachstan) coalfield in 1972. The technological scheme of biotreatment of gas-content and moderately thick coal seam kig at mine named after Kalinin in the basin has been tested. The depth of the seam was 280 m and natural gas-content was 13-15 m^3/t with natural temperature 20 - 22°C. For biosuspension feed the well with a diameter of 98 mm had been drilled from the surface to the seam. Two tanks with volume of 8 m^3 each were installed around a well's head. 5,000 m^3 of the biosuspension with 160 Mm^3 of air and microorganisms VSB1 - 70 with growth constant 0.07 hour"[1] was injected in the coal seam during 3 days.

Through the methane oxidation the gas emission into mine workings has been decreased in 3 - 4 times and it has been recorded as high as 0.8 - 1.8 m^3/min. This fact was recorded because methane content of the seam has been decreased on 4.5 m^3/t from natural methane content. The method referring to P&CM too is the real and effective means for decreasing of methane emission both in mine workings and in an atmosphere of the Earth. Thus this method can be considered as one of the innovative and efficient tool for environmental protection.

3. INTEGRATED ENERGY-SAVING AND ECOLOGICALLY CLEAN COAL-GAS ENERGY GENERATION COMPLEX

Coal reserves with favorable conditions at shallow depth are being rapidly depleted in all countries with developed coal industry. So in nearest future more coal will be mined from deeper levels with higher operational expenses and with lower labour productivity. Thus the solution of this problem is to be found in developing, promoting and implementing in industry unconventional geothermical coal mining and modern advanced clean coal technologies.

The "Coal-GasCMethaneVElectricity" concept actually presents a synthesis of the four technological components: coalbed methane drainage through boreholes drilled from the surface; coal gasification both in situ and in-the cycle; gas-steam turbines combined cycle electric power generation; borehole hydraulic coal mining technique can be alternative to coal gasification in situ.

Unconventional geotechnological coal mining enables us to mine difficult coal reserves with higher economical and socio-ecological efficiency. Significant increase in efficiency, cardinal humanization of coal mining and basic improvements in environment protection would be achieved adopting this technique. This new concept of unconventional coal mining and utilization technology has suggested integration of coalbed methane drainage, coal gasification with coal-gas combined cycle and transformed in the innovative method of coal seam mining (Vasyuchkov, Vorobjev, 1995).

The new method of ecologically clean and resource saving coal-gas electricity is protected by a patent of Russian Federation (1995) and has provided a challenge of modern level of technologies. On mining side borehole mining is used for coalbed methane extraction with vergin coal gasification in situ. On energy generating side the integrating coal gas combined cycle is planned (Fig. 1). All underground operations are performed through the boreholes drilled from the surface. A mining area is divided into panels. While panel I is being developed with two inclined boreholes, well connection is being done in panel II; coalbed methane extraction is being performed in panel III, and coal mass in panel IV is being gasified. As a result of these operations fuel gas mixture of coalbed methane with generated synthetic gas is produced. This mixture is used for fueling mine mouth electric power plant with gas and steam turbines working in tandem combined cycle.

Potential areas of the application of this innovative concept are as follows:

- coalfields with limited reserves of steam coal located in remote regions with no infrastructure;
- section of coalfields with removal reserves;
- re-exploitation of coal deposits;
- coalfields with coal reserves unsuitable for conventional coal mining due to a great depth, thin seams, high ash and sulphur content;
- coal seams liable to spontaneous combustion;
- coal measures prone to coal-gas outbursts;
- highly gassy coalbed and geological disturbed coal deposits.

Comparative economic-ecological appraisal indicates the certain advantages of unconventional coal-gas electricity technology over conventional coal-electricity technology. Relative resource-saving assessment for both traditional and unconventional technologies shows total energy efficiency of 8 - 10 % in conventional technology while in unconventional technology energy efficiency is as high as 17 %. Energy balance of one of the unconventional coal-gas-electricity is presented in diagramme (Fig. 2). Designations of the elements of the diagramme is listed.

CONCLUSIONS

Geotechnical methods for coal mining and utilization presents innovative technique which could provide the highest efficiency, natural resources conservation, environment protection and humanized and ecologically clean coal-gas-electric production. Coal mass treatment by physical-chemical and microbiological methods facilitate the complex processes and enabling to reach the highest production levels and energy efficiency.

Thus the innovative unconventional coal-gas electricity technology being widely implemented would result in significant increase of economic potential of counties as well as to sustainable development of their national economy.

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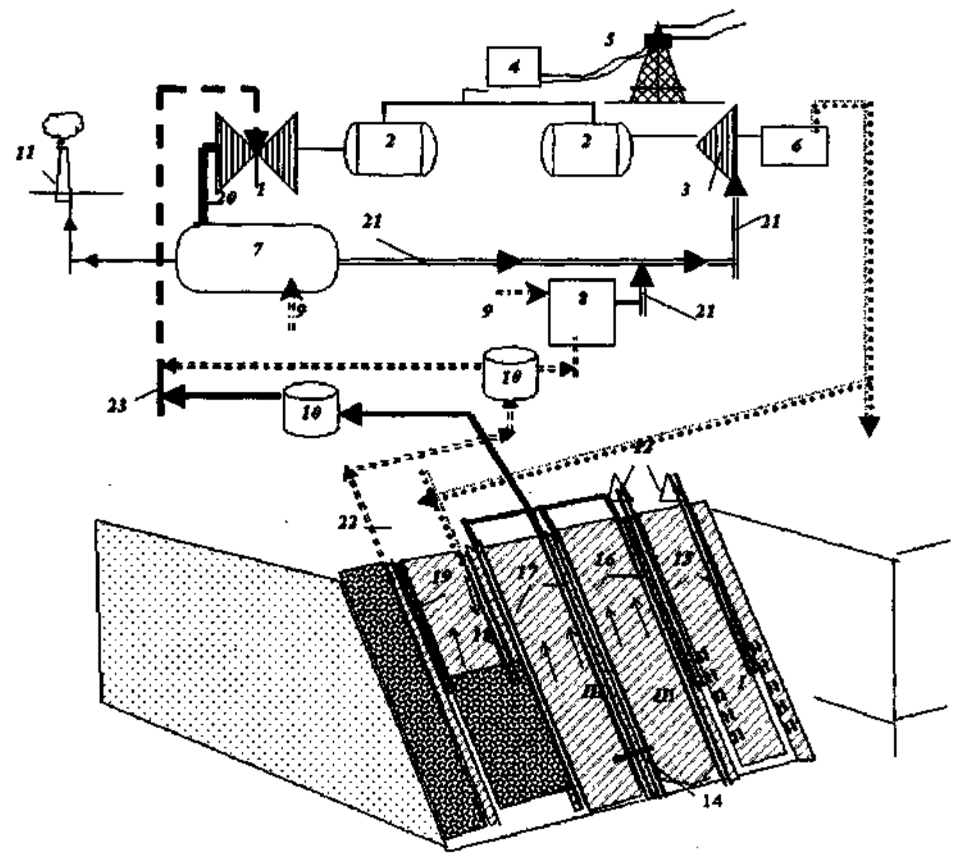

Fig. 1. Locally integrated coal-gas electric power complex:

1 - gas turbine
2 - generator
3 - steam turbine
4 - transformer
5 - transmission line
6 - air/oxygen buster
7 - heat recovery steam generator
8 - boiler-steam generator
9 - water
10 - gas cleanup
11 - stack
12-drilling rig
13 - fire face
14 - initial connection channel

15 - inclined well in drilling
16 - inclined well in the developed panel
17 - methane drainage well
18 - air /oxygen/ steam well
19 - gas producing well hot gas from gas turbine
21 - steam
22 - synthetic gas
23 - methane

- methane
- synthetic gas
- steam

- steam/flue gasses
- water
- air/oxygen
- methane-gas mixture

I - panel in development
II - panel in well connection and hydrofracturing phase
III - panel in coalbed methane extraction period
IV - panel in coal gasification period

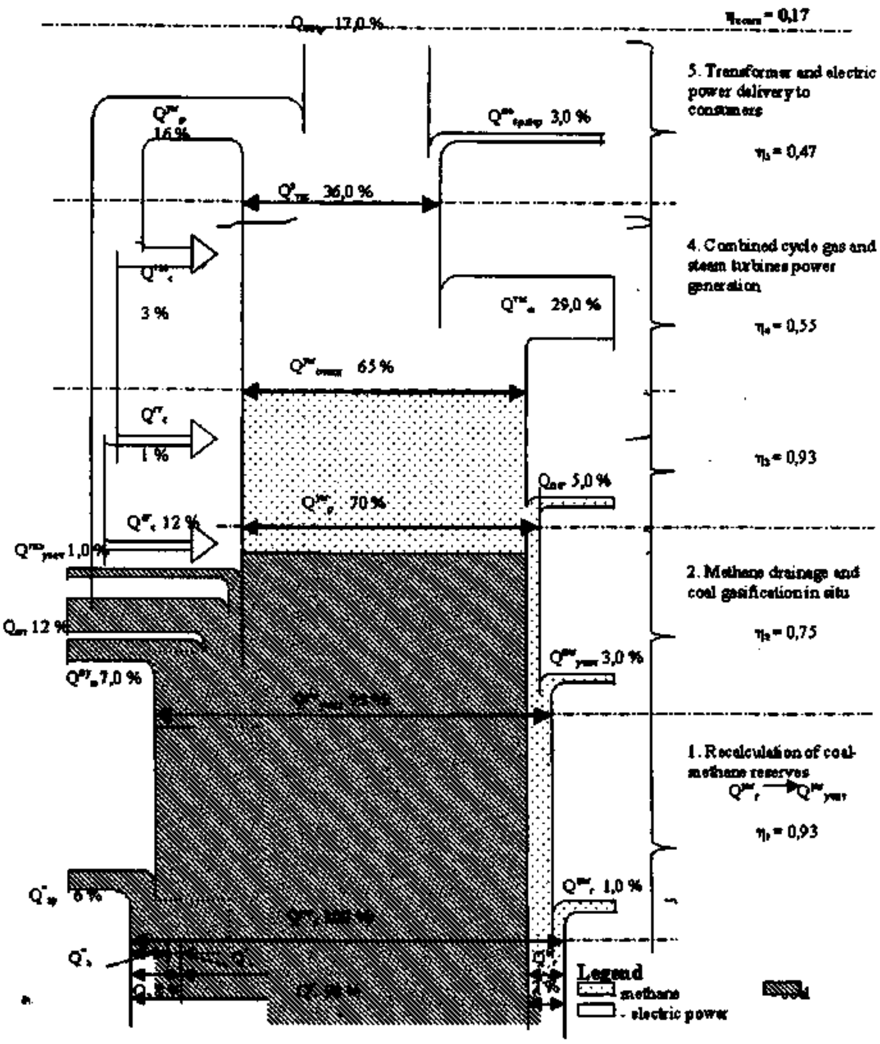

Fig. 2. Energy balance of one of the unconventional coal-gas-electricity enterprise:

- $Q^{\text{у}}_{\text{г}}$ - geological coal reserves, t e e .
- $Q^{\text{м}}_{\text{г}}$ - geological reserves of coal and methane, t.c.e.
- $Q^{\text{ум}}_{\text{г}}$ - geological reserves of coal and methane, t.c.e.
- $Q''_{\text{зу}}$ - non-minable coal reserves, t.c.e.
- $Q^{\text{пм}}_{\text{г}}$ - non-extractable methane reserve coal and rock mass
- $Q^{\text{учит}}_{\text{ум}}$ - measured coal-methane reserves
- $Q^{\text{пм}}_{\text{учит}}$ - coalbed methane losses, %
- $Q^{\text{пу}}_{\text{н}}$ - total coal losses underground in coal gasification in situ
- $Q_{\text{пт}}$ - heat losses underground in coal gasification in situ
- $Q^{\text{газ}}_{\text{утеч}}$ - gas leakage (losses) in coal gasification in situ
- $Q_{\text{птт}}$ - energy losses in gas cleanup and transport processes
- $Q^{\text{тэс}}_{\text{п}}$ - total energy losses in steam-gas turbines
- $Q^{\text{пэ}}_{\text{тр.пер}}$ - energy losses in transformers an electric transmission
- $Q^{\text{ум}}_{\text{р}}$ - total energy consumption for internal needs of LCGEC
- $Q^{\text{тэс}}_{\text{с}}$ - total energy consumption for internal needs of thermo-electric plant
- $Q^{\text{гт}}_{\text{с}}$ - international energy consumption for gas clean up and gas delivery
- $Q^{\text{пг}}_{\text{с}}$ - international energy consumption for CBM drainage and coal gasification in situ
- $Q_{\text{потр}}$ - net energy delivered to the consumer
- $Q^{\text{ум}}_{\text{р}}$ - energy of coalbed methane and synthetic coal gas
- $Q^{\text{ум}}_{\text{очищ}}$ - cleaned gas-methane mixture
- $Q^{\text{э}}_{\text{тэс}}$ - energy generated at electric thermo plant
- $\eta_{\text{комп}}$ - total efficiency for complex (LCGEC)