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THE BASIC TECHNOLOGICAL CONDITIONS OF UNDERGROUND COAL GASIFICATION (UCG)

1. Introduction

Polish mining is characterized with sophisticated technical culture resulting from both hundreds of years of experience and widely implemented technical and technological novelties. Currently there are no technical contraindications to make the coal seam or its fragment available even if it is located in very difficult conditions of deposit. Currently it is only determined by the feasibility of underground coal exploitation that is costs on each stage of mining.

Mining technologies and assistive technologies are used in strictly defined environmental conditions. Limitations resulting from the high specialization of mining technology, machinery and equipment, will determine the availability of the deposit. The decision to start mining operations is determined by the safety of both staff, and mining machinery and equipment.

Given the economic aspects of the opening of deposits of coal or fragment thereof, the use of a group of existing mine workings may determine implementation of the technology of underground coal gasification. The concepts of the underground coal gasification were developed in 1912 by W. Ramsay in England [7]. In the last century coal gasification technology had had a number of modifications as a result of which on an industrial scale, this process is conducted in a surface UCG plants [1, 7]. Underground coal gasification on an industrial or semi industrial scale is carried out by vertical and directional boreholes from the surface. The cost of drilling into coal seams at great depths, limits the viability of this technology [1, 8].

Use of mine workings for the construction of an underground coal gasification plant (UCG plant) is very attractive, but the decision to build a UCG plant must take into account geological and mining conditions characterizing the rock mass in the vicinity of the proposed generator [3]. In underground mines there are a large number of geological disturbances and historical exploitation issues; hence coal gasification in the coal deposit can

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cause uncontrolled migration of a number of toxic or asphyxiating components [4, 6]. A large number of restrictions on the construction of a UCG plant make the attempts to apply this technology research based only.

Of special interest are the results of work carried out by the Central Mining Institute in the 1960s in the “Mars” and “General Zawadzki” coal mines [8]. It should be emphasized that a return to underground coal gasification technology as a results of the progress of technology of control and isolation of this the process and technology of the effective combustion of low calorie gases.

In terms of the technology used in the mining industry and of the technology of underground coal gasification, coal deposit can also be categorized in terms of gasification.

2. Categorization of resources from the point of UCG

When considering mining operations and technology related to underground gasification it is important to estimate their the implementation in complex geological conditions. Factors limiting the possibility of carrying out those works may be: large depth and high temperature of rock mass, complicated tectonics of the deposit, extremely high or very low strength parameters of rocks, plasticity of rocks, and high levels of rockburst, methane, fire or water hazard.

The works required for opening deposits and preparing them for gasification requires the obtainment of a range of information necessary for its qualification for the UCG. As the amount of available information and its reliability increases the possibility of accurate determining which UCG category of UCG exploration of the deposit may include the available resources and also increases in those deposits available. The merits of the construction of the UCG plant can therefore only be considered based on a set of obtained information /parameters of a specified number of beds at each stage of mining.

At the stage of research drilling and shaft excavation it can be determined whether the resources can be exploited on an industrial scale and thus be categorized as anticipated economic resources for UCG, or if not, as anticipated subeconomic resources for UCG. Consecutively, with the development of mining operations, more accurately obtained information will or will not allows one to qualify them as economic resources that can be intended for gasification. At the stage of mining works, the seam is qualified for extractable resources (operative resources) or reserves (nonoperative resources) and UCG can be evaluated at this point. It should be emphasized that with the classification of resources the anticipated subeconomical, subeconomical reserves (nonoperative) in terms of UCG, does not exclude this part of deposit for the operation of traditional mining technologies.

2.1 Anticipated economic resources for the UCG

Drilling work and excavation from the surface is performed for opening of coal deposits coal, separation of the mining level and connection to the surface for transport and ventilation. These works allow basic information about the geological conditions of rock mass to

be assessed, as well as the physical and mechanical properties of rocks and about or location of water aquifers. All of these natural features of rock mass determine the possibility of exploitation on an industrial scale. Identified and difficult geological conditions can result in halting the planned works for the UCG in extreme cases. Also the weak property of rock mass features can be eliminated and known and used technologies of digging or drilling necessary for the UCG can be applied.

The factors that may eliminate, impede or prevent the use of devices for the purpose of drilling include:

- occurrence of water horizons and levels,
- occurrence of difficult to mining rock which are not be possible to of excavation,
- occurrence of fracture zones in the vicinity of coal seam for UCG.

The basic parameters to be defined and quantified include:

- the depth of the deposit — in the case of underground coal gasification at a shallow depth, a release of gasification products to the surface in an uncontrolled way may occur. For the coal deposits in areas of existing mines the optimum depth of the coal seam thereof designed for underground gasification is in the range of 600–1200 m,
- thickness and dip angle, quality parameters and the strength parameters of coal and rocks:
 - minimum thickness ≤ 2 m,
 - dip angle around 70° ,
 - moisture of coal $< 15\%$,
 - ash content $< 30\%$,
 - volatile matter content $> 35\%$, in Polish conditions, volatile matter content above 35% is characterized by coal type 31 and 32,
 - calorific value of > 20 MJ/kg,
 - sulfur content $< 1\%$;
 - no harmful elements that is radium and radon [5],
 - coal type — for optimum UCG — coal type 31 and 32.
- thickness, quality and strenght parameters of rock mass surrounding the UCG plant:
 - thickness of rock mass that provides its robustness > 10 m,
 - impervious fractions that is mudstones and claystones < 0.01 ,
 - strenght of rock mass surrounding UCG generator to compression $R_c \geq 40$ MPa, to tension $R_r \geq 0.4$ MPa.
- lack of tectonic disturbance that is the degree of faulting of the deposit < 1.5 and the ratio of faulting $K < 50$ m/ha.
- hydrogeological conditions
 - porosity of the rocks surrounding UCG plant $< 5\%$,
 - fracturing $< 5\%$,
 - permeability of the rocks surrounding the UCG plant $< 5.0 \cdot 10^{-6}$ m/s,
 - hydraulic conductivity $< 5\%$,
 - water absorption of $< 5\%$,
 - 100% of the tightness of rock mass in the section of UCG generator — aquifers.

Figure 1 shows schematic classification of coal resources for UCG from technological reasons, and general characteristics of the of the rock mass.

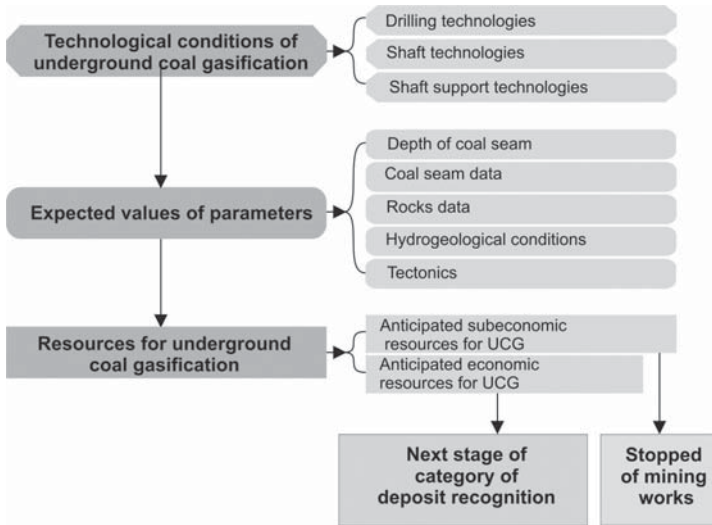


Fig. 1. Anticipated economic resources and anticipated subeconomic resources for UCG based on technological conditions and basic data of rock mass

Sinking shafts or drilling holes from the surface in a limited way to determine the basic parameters characterizing the location of deposit and nature of tectonic disturbance. Only excavation of workings in the deposit allows for better identifying its qualities for the UCG.

2.2 Economic resources for the UCG

The next stage of preparing the deposit for underground coal gasification is to provide horizontal and vertical workings and boreholes. The aim of these works is the separation of floors and exploitation fields, isolation of the pillars of exploitation, provision of communications, ventilation of mine workings and drainage.

Geological and mining conditions for the provision and preparation of the coal seam in order to conduct the process of underground coal gasification using the workings necessitate the need for a number of mining technology, including:

- excavation of accessing and preparatory corridor workings by mechanical method or using techniques of blasting,
- excavation of shafts,
- technology of casing with particular emphasis on integrity of vicinity of coal seam,
- drilling technologies to drill workings, and drilling prevention research,
- ventilation technologies.

These mining technologies can be used in a safe and efficient manner. Factors hampering its use also including economic reasons should be distinguished. The main reasons which prevent the possibility of their use include:

- very strong rock requiring the use of special techniques of blasting,
- a high level of hazards: rockburst, methane, fire, water,
- extensive fracture zone in the rock mass,
- presence in the workings of gases with concentrations exceeding the limit values.

In the course of mining works data characterizing the rock mass is obtained to determine the specific mining technology and UCG technology. Acquired range of information also allows forms from a technological point of view, to qualify coal deposits as technological and economical resources for underground gasification. Failure to meet criterion / limit values of specified parameter group qualifies the deposit as subeconomic resources for UCG. We can conclude that parameters and conditions qualifying resources as industrial in terms of capacity of their gasification are as follows:

- coal brevity $f < 1.2$,
- coal workability $U < 1.35$,
- methanity of the coal seam $< 2.5 \text{ m}^3 \text{ CH}_4/\text{Mg}_{\text{csw}}$,
- the ability of coal to spontaneous combustion $< 80^\circ\text{C}/\text{min}$,
- no hazard of outbursts of coal and rock,
- the natural flow of water into the UCG plant $< 0.5 \text{ Mg H}_2\text{O}/\text{Mg}$ of coal,
- no hazard of dust,
- no hazard of rock burst.

Figure 2 shows economic resources and subeconomic resources for UCG based on technological conditions and detailed data of rock mass.

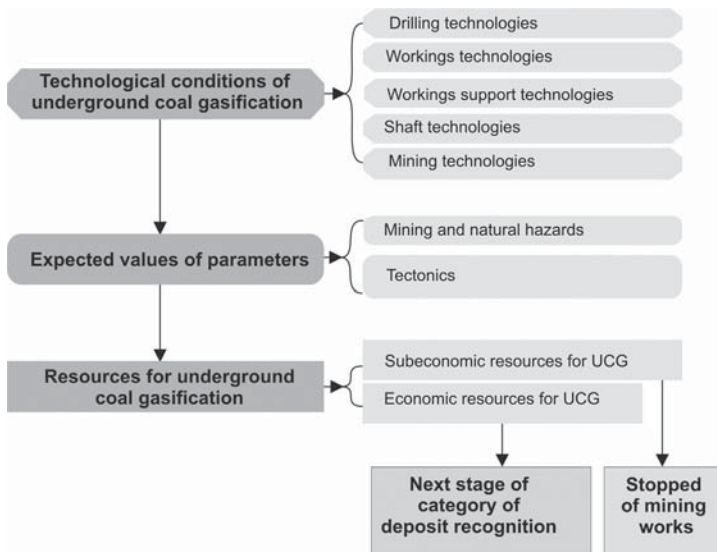


Fig. 2. Industrial resources and nonindustrial resources for UCG based on technological conditions and detailed data of rock mass

2.3 Extractable resources of UCG

The conditions necessary for underground coal gasification are to maintain the infrastructure of corridor workings in a stable rock environment [2, 4]. This requires the application of proper casing or its reinforcements and strengthening or sealing the rock in its vicinity. At this stage of preparing the coal seam for gasification, mining hazards may dictate that you should refrain from the gasification of an available part of the coal seam until conditions for the safe implementation of the UCG can be met therefore constant monitoring of risks must be carried out prior coal to the gasification process. Continuous monitoring of hazards and the process of coal gasification in the coal seam allows us to introduce new or modified mining technologies used to ensure process technical and general safety.

When applied mining technologies become inefficient, coal deposits previously classified as technologically extractable resources (operative resources) should be reclassified to technological reserves (nonoperative resources).

An important stage of underground coal gasification is the UCG plant liquidation phase. Lack of effective liquidation of the UCG plant technology or difficulties associated with this element of the process may cause a threat to the safety of the mine. The uncontrolled flow of gasification products into the mine ventilation network can cause abnormal climatic and ventilation conditions. As a consequence part of the seams already available may be abandoned and be requalified for technological reserves (nonoperative resources).

The toxic gas flow process to the surface of the rock mass through the discontinuity network also threatens the ecosystem, so the case should also be exempt from this method of exploitation of the seam.

Figure 3 shows extractable resources and reserves for UCG based on technological conditions and detailed data of rock mass.

3. Summary

The possibility to apply mining technology for UCG allows the classifying of coal reserves. This is determined by natural conditions of occurrence of the coal seam and the economic balance of applied technologies. In view of mining technologies and chronology of the provision of the coal seam, coal resources can be classified for the underground gasification as:

- Technologically anticipated economic and subeconomic resources - defined at the stage of research drilling and the drilling of shafts from the surface. In the case of the positive evaluation of the works, resources should be considered as technologically economic. Otherwise, they should be classified as technologically anticipated subeconomic resources.
- Resources technologically, economic or subeconomic are defined during the execution of the network corridor workings, drilling and occasionally vertical workings. The successful implementation of technology related to these mining works allows for the classifying of the coal seam in different regions of and levels to technologically industrial

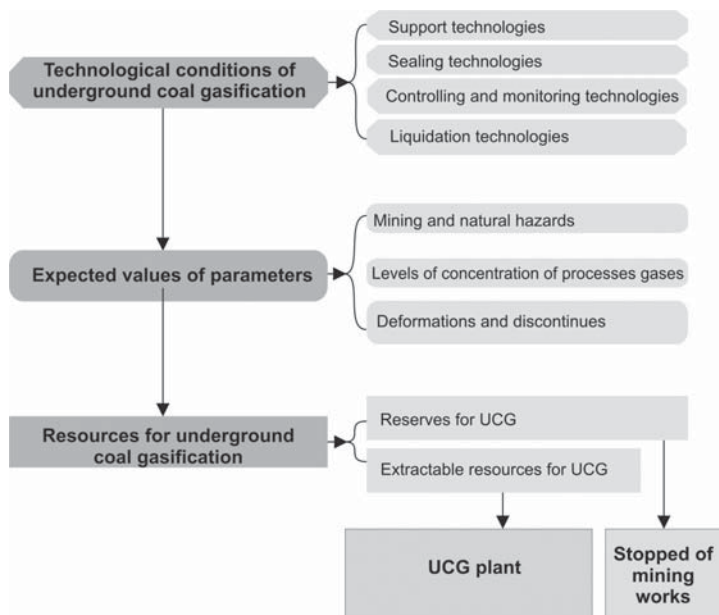


Fig. 3. Extractable resources and reserves for UCG based on technological conditions and detailed data of rock mass

for UCG. The ineffectiveness of mining technology, at this stage of work qualifies resources as technologically subeconomical for UCG.

- Extractable and technologically available resources and reserves can be distinguished during the construction phase of the UCG plant and of technological, corridor workings used for the underground gasification of coal seam. If technology used to strengthen the mining workings and rock mass sealing meet the requirements of then limited by resources such workings can be classified as extractable technologically. Otherwise, such resources become reserves (nonoperative resources).

In conclusion, in every phase of the provision of the coal seam for the construction of the UCG plant, there may be circumstances in which the mining works should be discontinued. This is due to lack of experience in underground coal gasification and due to lack of positive assessments up-to-date methods, developed for UCG, technologies, together with their full economic analysis.

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