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Reprint of "The possibility of underground gasification of lignite from Polish deposits"

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ABSTRACT

The paper focuses on the possibility of underground gasification of lignite from Polish deposits. Lignite deposits in Poland are part of the European Lignite Formation. The profile of coal bearing sediments in Poland is several hundred meters (Paleocene–Pliocene), but it is fragmented vertically and is not complete at any point. It includes marine and brackish sediments, as well as Paleogene and Neogene land sediments. Lignite deposits originated both in platform areas and sedimentary basins in orogenic belts. The coals form extensive seams or lenses ranging from few meters to several dozen meters in thickness. There are 90 documented lignite deposits in Poland.

Currently, geological resources of lignite are about 26,132 Mt. On the Polish Lowland, ten lignite (eight major and two accompanying) seams have been distinguished within the Paleogene and Neogene stratigraphic columns. Only three of them (1st Mid-Polish, 2nd Lusatia, 3rd Ścinawa), and locally-five (additionally 2ndA Lubin and 4th Dąbrowa) are important from the economic point of view.

The annual production of lignite in Polish open cast mines amounts to 65.0 Mt per year, while it is primarily used by power plants. However, chemical processing of lignite is not yet developed. It is planned that pilot plants are to be developedfor underground lignite gasification in the near future. The geological structure of the Tertiary coal-bearing formation in the Polish Lowland was the basis for the development of guidelines and parameters for criteria verification of resource base (ortho-lignite) for underground coal gasification (UCG) in Poland. Lignites from the Polish coal deposits havethe characteristics of low rank coal (mean Rr 0.2–0.35), an average carbon content at around 62–65% C, high moisture content (>50%) and net calorific value (NCV) 6–20 MJ/kg (mean 8.0 MJ/kg).

Petrographic composition of lignite (>80% humic components) makes it a preferred material for chemical processing. The available resources and lignite deposits have been verified on the basis of the assumed geological and technological criteria. Since the geologic and reservoir conditions are accompanied by the requirements of environmental protection, protection of groundwater reservoirs of drinking water and distance requirements between the gasification plants and residential buildings, roads and transmission lines, a significant reduction in coal resources suitable for underground gasification in Poland occurred. The aforementioned criteria were applied to the initial verification of lignite resources in the Polish deposits. The deposits useful for underground gasification are mainly located in the area from Głogów up to Ściniawa and Legnica. Some individual deposits are scattered in different locations (e.g. Węglewice, residual part of the Turów deposit).

1. Introduction

The term underground coal gasification (UCG) was introduced in the United Kingdom in 1868 by William Siemens, who was the first to propose the underground gasification of coal and waste in mines. Russian chemist Dmitri Mendeleev developed the Siemens' idea over the next years. Underground coal gasification (UCG) is a method of converting unworked coal into a combustible gas for power generation, industrial heating or the manufacture of hydrogen, synthetic natural gas or diesel fuel. The basic UCG process involves drilling two wells in the coal, one for injection of the oxidants (water/air or water/oxygen mixtures) and others to bring the product gas to the surface.

The coal at the first well is heated to temperatures that would normally cause the coal to burn. However, careful regulation of the oxidant flow prevents the coal from burning and the coal is separated into the syngas. Then, the syngas is drawn out of the second well. The first experimental work on UCG started in 1912, following which the Skochinsky Mining Institute launched a research and development program to compete with the Germans, who focused on a rapidly growing technology of processing coal into syngas using the Fischer Tropsch

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process. Since then, a number of key studies have been carried out in many parts of the world, all of which are aimed at the development of new UCG technologies (Bhutto et al., 2013). For a certain time, there was no interest and research on UCG due to the use of cheap natural gas. Now, however, the demand for energy characterized by lower emissions, security of supply, and in light of dwindling reserves of oil and natural gas, UCG has once again become a subject of interest and research.

Although the UCG studies have been conducted mainly in Australia, installations are also being built in other countries, such as New Zealand, South Africa, China, USA, Spain, Turkey, India, Indonesia, Vietnam, Pakistan and the United Kingdom. The pace of new projects continues to grow and includes commercial projects on a large scale for both bituminous coal and low-rank coal.

This paper focuses on the possibility of underground gasification of lignite from Polish deposits. Analyzing the existing installations for low-rank coal, it can be concluded that the most gasified coals included low rank B and subbituminous coal (subbituminous coal according to the ISO classification) (Bhutto et al., 2013; Couch, 2009; Olness and Gregg, 1977). Gasification attempts of soft brown coal (lignite C), which can be found in Poland, were carried out only in the Moscow basin and with a little success.

The criteria that must be met by the coal deposit, to be qualified for the underground gasification, include both the technological and geological criteria. These criteria have been the subject of several works, including Armitage and Burnard (2003), Bhutto et al. (2013), Shafirovich and Varma (2009), Shafirovich et al. (2008), Thomson and Mann (1976) andWilliams (1982). In Polish literature, the criteria for underground gasification have been presented by: Hajdo et al. (2012), Kozłowski (2008), Nieć (2012) and Nowak et al. (2010, 2011a, 2011b). However, it should be noted that the criteria for installation construction sites designated by other researchers are closely related to the availability and location of deposits, which determine the geological structure.

2. Geological and depositional conditions for low-rank UCG and the coal-bearing geological formations in Poland

Lignite deposits in Poland can be divided into several regions, which are characterized by a different geological structure (Kasiński and Piwocki, 2002). When choosing the installation location, technological properties of coal and the geology of coal deposits and rock overburden, which determines the possible use of UCG, are very important. The most important characteristics that affect the possibility of UCG include:

- geologic structures both above and below the coal seam. Especially the geomechanical properties of the coal seam, overburden, and the hydrogeological properties.
- depth, thickness and dip of the coal seam
- coal seam integrity
- coal characteristics — particularly coal rank and reactivity, including ash content, moisture, sulfur and methane content — defining geochemical and mineralogical characteristics of the coal seam and surrounding rocks including the possibility of potential contaminants such as sulfides, heavy metals, phenols, etc.,
- permeability of the roof, depending on the pore structure and the presence of natural fractures. Furthermore, fault planes or shear zones near the seam are of great importance, as they can provide leak paths for syngas.
- expected subsidence. The range and nature of the subsidence of the surface depend on the type of overburden rocks. At the same time, it should be noted that the majority of coal ash remains underground and acts as a buffer to reduce the surface subsidence.

When it comes to Polish low-rank coal, two deposit types can be distinguished: subbituminous coal and lignite (low rank C). Lignite is common in the Paleogene and Neogene formations of the Polish Lowland. Subbituminous coal occurs locally in the Cretaceous and Jurassic formations and in the Carpathian Foredeep.

The Miocene lignites, mainly 1st, 2nd and 3rd group of seams, are of dominant industrial importance because of their abundance and depth allowing opencast mining. Other Paleogene and Neogene coal-bearing series (4th–7th group of seams) are classified as subeconomic resources due to the depth of occurrence, generally low thickness and their low abundance (Fig. 1). Some of the lignites not available for industrial use today, such as Paleocene, Eocene, Upper Oligocene, as well as subeconomic Miocene coals occurring at favorable lithological conditions — e.g. in impermeable sediments — can be used for a possible underground gasification in the future.

Lignite deposits were divided into eight regions (Fig. 2). The deposits in individual regions are shown in Figs. 3–10.

2.1. The form and structure of the coal seam

The coal occurs in seams, coal-bearing series, deposits and coal basins. The seam is the main lithological factor, determining the economic value of coal-bearing series.

Polish lignite deposits contain one or more, often several seams. Hence their name — one or multi-seam deposits (Kasiński and Piwocki, 2002.) In terms of the suitability for underground gasification, the most useful are single seam deposits, including lens type seams and widespread seams.

The following morphological types, regardless of their genesis and forms, can be distinguished in Polish lignite deposits: 1) seam-type, 2) lens-type, 3) relict, 4) salt domes, 5) tectonic, and 6) glacitectonic. The seam-type deposits occur mainly in south-western Poland, in the western part of the Fore-Sudetic Monocline. The other Miocene coal-bearing series are dominated by lens-type deposits of different sizes, ranging from very small to large, e.g. Konin, Adamów, Oczkowie and others. Relict deposits can be found in Ochle and in the area of Konin.

Coal deposits occurring in the salt domes are associated with a reduction in surface morphology of the dome cap, although their outlines are often Mesozoic formations with salt diapir squeezed upwards. The deposits of this type include Rogóźno north of Łódź, Lubień and Łanięta in the Kujawy Region. The deposits which occur in grabens are the most abundant in lignite. So far, over a dozen of them have been identified. Their main directions are NW–SE or NS — including the deposits of the Poznan group (Mosina, Czemin, Krzywin, Gostyń), Szamotuły, Nakło, and SW–NE (including the Bełchatów, Szczerców and Złoczew deposits). The Turów deposit, surrounded by the Proterozoic crystalline rocks of the Lusatian Massif, is also classified as tectonic type deposit. The SW–SE deposits are — to some extent — related to the late tectonic movements of the Mid-Polish aulacogen between East European Precambrian platform and young Paleozoic platform.

Natural cracks and fissures in the coal and its surroundings are the result of its geological history and — to a large extent — depend on the rocks building the rock mass. Tectonics of the rock mass and the closest environment, such as faults, cracks, intrusions and folds, might cause excessive supply of water to the gasifier as well as the migration of gases and pollutants into the environment. Stratigraphic throw larger than the thickness of the coal seam can be a serious obstacle to UCG. Therefore, the areas that are free of major faults (at least 50 m from the proposed gas generator) should be preferably selected to UCG. According to the current criteria, UCG requires no cracks and faults.

Due to intense tectonic activity in areas of grabens (mainly Bełchatów) and a large number of faults affecting the coal-bearing formations, it is very important to limit the UCG in the areas of salt domes and grabens.

Glaciotectonic deposits include those deposits whose current form was influenced by mechanical pressure from the advancing glacier. They usually have the form of elongated zones, semicircular zones, thrust folds or are irregularly deformed. The most important deposits are located in the Muskau Bend (Łuk Mużakowski), Żary west of