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Underground Coal Gasification (UCG): The Opportunities to Increase Natural Resource Production in Indonesia

Muhamad Taufik Maryudi[1, *], Ryan Aristo Nusantara[1], dan Ridwan Silalahi[1]
[1] *Departemen Teknik Geologi Universitas Diponegoro, Jalan Prof. Soedarto, Semarang, 50275*
**E-mail korespondensi: opickmaryudi@gmail.com*

Abstract. *Underground Coal Gasification (UCG) is the gasification of coal in-situ, which is achieved by drilling boreholes into the coal and injecting water/air or water/oxygen mixtures. It is both an extraction process (like coal mining) and a conversion process (gasification) in one step, producing a high quality, affordable synthetic gas that can be processed to provide fuels for power generation, diesel fuels, jet fuels, hydrogen, fertilizers and chemical feed stocks (Clean Coal Ltd, 2009). The process of coal gasification in a surface, gasifier can be replicated underground by drilling into the coal seam, injecting air or oxygen, and gasifying the coal seam in situ. The produced gas is transported to the surface (Walker, 1999). UCG have a lot advantages especially in environmental and economic issues, such as reducing gas emissions (CO_2, SO_2, NO_x), low operational installation cost, and syngas can distribute directly. The operating life of a UCG operation can be broadly broken down into four steps. The advantages of Underground Coal Gasification based on two aspects, environmental aspect and economic aspect. Based on that opportunities of UCG the Indonesian Government have to consider alternative energies which may be cheaper and cleaner unconventional energy. So this technology should be investigated for implementation in Indonesia.*
Keywords: *Underground Coal Gasification, Process and Advantages.*

INTRODUCTION

In Indonesia, the amount of Indonesia's coal resources totals 161 billion tons of coal and if it is exploited can reach needs of Indonesia energy up to 150 until 200 years later. 120 billion tons of coal can reach by open pit method and another 41 billion using underground mining methods (Badan Geologi, 2012). According to BP's statistical review of world energy 2011 (**Table 1**), Indonesian coal reserves reach 0.6% of world coal reserves and it is in 9th position in the world's largest coal production after United States, Russia, China, Australia, India, Germany, Ukraine and Kazakhstan. Based on the quality of coal in Indonesia, it has a low level of ash and sulphur content, but the volatility and water content including on high level of coal. The average value of calorie 5100 – 6100 cal/gr and water content on 10 – 25%, coal rating in Indonesia generally included in Sub-Bituminous rank. Indonesia has total coal resources for 63.10% and total coal reserves of 59.80%. The average depth of coal in Indonesia is on 100 m until 500 m.

The high level of coal production in Indonesia can make some environmental issues which come from mining activities, distribution activities or coal processing. Because the burning coal produce pollution gases, such as CO_2, SO_2, NO_x and C_xH_y this process is inefficient and the important things that causes environmental issues. Underground Coal Gasification (UCG) is one of technology that can reduce environmental issues.

Underground coal gasification (UCG) is a process in which coal is converted in situ to a combustible gas that can be used as a fuel, chemical feedstock and syngas. UCG is a process used to produce gas, primarily hydrogen, carbon monoxide, carbon dioxide, and methane by partially combusting underground coal in the presence of water and a controlled oxygen supply (Walker, 1999). Underground Coal Gasification just using two wells so that don't need lots of space. First well used for catalyst injection and another well used for production well.

Underground Coal Gasification (UCG) is the cleaner unconventional coal utilization than others coal gasification method to prevent environmental issues for increasing economic and safely coal production in Indonesia.

METHODOLOGY

This paper is an overview of published literature contained in books, journals, and internet media.

DISCUSSION

Underground Coal Gasification (UCG) is the gasification of coal in-situ, which is achieved by drilling boreholes into the coal and injecting water/air or water/oxygen mixtures. It is both an extraction process (like coal mining) and a conversion process (gasification) in one step, producing a high quality, affordable synthetic gas that can be processed to provide fuels for power generation, diesel fuels, jet fuels, hydrogen, fertilizers and chemical feed stocks (Clean Coal Ltd, 2009).

Gasification process is done by drilling to the coal seem and injecting of air or oxygen. This is like in coal mining activities (extraction process) and coal gasification (conversion process) in one process. How the underground coal gasification (UCG) method works can be seen in **Figure 1**. The main gas produced is CO_2, CH_4, H_2, CO and O_2. CH_4 (methane) is a product produced by a pyrolysis process and occurs at low temperatures and high pressures. As the combustion process happen and groundwater get in to the location, it will be produced another product, such as benzene, toluene, ethyl-benzene and xylen (BTEX), phenol, coal ash and tar, aromatic hydrocarbons and sulphides, NOx, NH_3, boron (B), cyanide, CO and H_2S. This gas can be used for power plants, and chemicals that can be used as the pharmacy.

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Table 1. World Coal Reserves, Red Circle Shows Indonesian Coal Reserves Reach 0.6% of Word Coal Reserves (BP's Statistical Review of World Energy, 2011 in Pratiwi, 2012).

Coal

Proved reserves at end 2010

Million tonnes	Anthracite and bituminous	Sub-bituminous and lignite	Total	Share of total	R/P ratio
US	108501	128794	237295	27,6%	241
Canada	3474	3108	6582	0,8%	97
Mexico	860	351	1211	0,1%	130
Total North America	112835	132253	245088	28,5%	231
Brazil	–	4559	4559	0,5%	*
Colombia	6366	380	6746	0,8%	91
Venezuela	479	–	479	0,1%	120
Other S. & Cent. America	45	679	724	0,1%	*
Total S. & Cent. America	6890	5618	12508	1,5%	148
Bulgaria	2	2364	2366	0,3%	82
Czech Republic	192	908	1100	0,1%	22
Germany	99	40600	40699	4,7%	223
Greece	–	3020	3020	0,4%	44
Hungary	13	1647	1660	0,2%	183
Kazakhstan	21500	12100	33600	3,9%	303
Poland	4338	1371	5709	0,7%	43
Romania	10	281	291	*	9
Russian Federation	49088	107922	157010	18,2%	495
Spain	200	330	530	0,1%	73
Turkey	529	1814	2343	0,3%	27
Ukraine	15351	18522	33873	3,9%	462
United Kingdom	228	–	228	*	13
Other Europe & Eurasia	1440	20735	22175	2,6%	317
Total Europe & Eurasia	92990	211614	304604	35,4%	257
South Africa	30156	–	30156	3,5%	119
Zimbabwe	502	–	502	0,1%	301
Other Africa	860	174	1034	0,1%	*
Middle East	1203	–	1203	0,1%	*
Total Middle East & Africa	32721	174	32895	3,8%	127
Australia	37100	39300	76400	8,9%	180
China	62200	52300	114500	13,3%	35
India	58100	4500	60600	7,0%	106
Indonesia	1520	4009	5529	0,6%	18
Japan	340	10	350	*	382
New Zealand	33	538	571	0,1%	107
North Korea	300	300	600	0,1%	16
Pakistan	–	2070	2070	0,2%	*
South Korea	–	126	126	*	60
Thailand	–	1239	1239	0,1%	69
Vietnam	150	–	150	*	3
Other Asia Pacific	1582	2125	3707	0,4%	114
Total Asia Pacific	159326	106517	265843	30,9%	57
Total World	404762	456176	860938	100,0%	118
of which: OECD	155926	222603	378529	44,0%	184
Non-OECD	248836	233573	482409	56,0%	92
European Union	5101	51047	56148	6,5%	105
Former Soviet Union	86725	141309	228034	26,5%	452

More than 500 years.
Less than 0.05%.

Source of reserves data: Survey of Energy Resources, World Energy Council 2010.

Notes: Proved reserves of coal – Generally taken to be those quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known deposits under existing economic and operating conditions. Reserves-to-production (R/P) ratio – If the reserves remaining at the end of the year are divided by the production in that year, the result is the length of time that those remaining reserves would last if production were to continue at that rate.

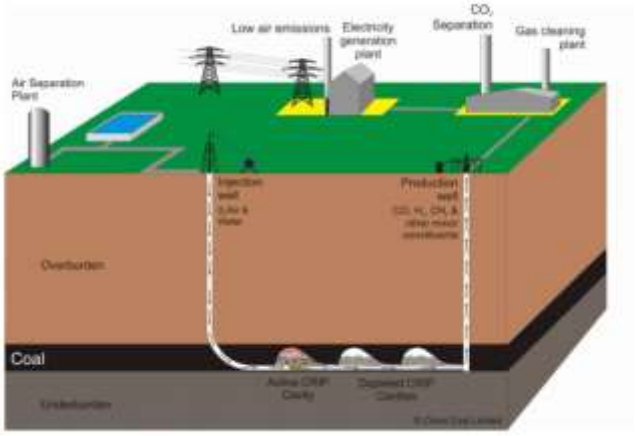

Figure 1. The Principle of UCG Process (Clean Coal Ltd, 2009)

Gasification provides many opportunities for pollution control, especially with sulfur emissions, nitric oxide, and mercury. UCG can increase coal production with more efficient utilization because it can be produce unprofitable coal (Burton, et al., In Zulfahmi et al, 2014).

The Procces of UCG to Produce Syngas

UCG is the process of the gasification of coal in-situ to produce a synthetic gas (syngas). The operating life of a UCG operation can be broadly broken down into four steps:

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Well Construction

Wells are drilled into the coal to allow for oxidant injection and product gas extraction. The wells are linked or extended to form an in-seam channel to facilitate oxidant injection, cavity development and syngas flow. The main idea in this well construction is to build injection well and production well. The link between the wells can constructed with in seem directional method (**Figure 2**) or reverse combustion method (**Figure 3**).

Figure 2. Directional Drilling (in-seam) illustration (Linc Energy, 2009)

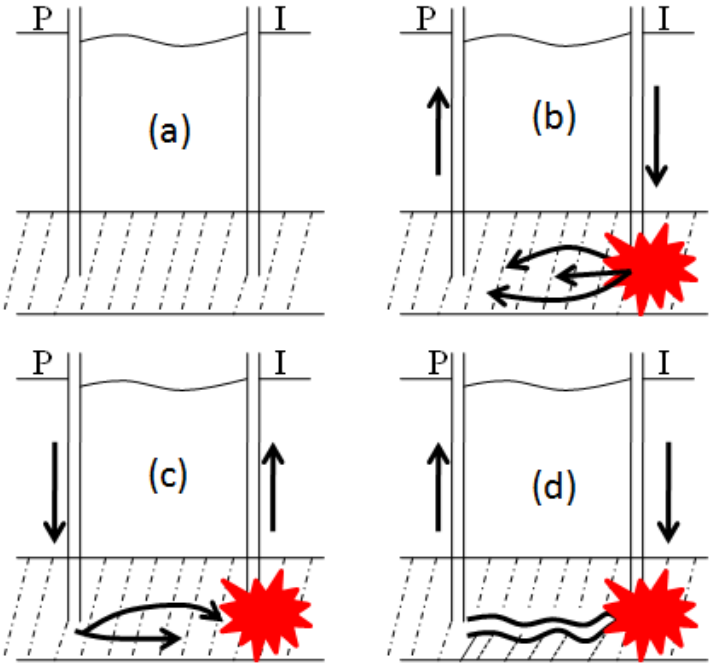

Figure 3. Reverse combustion illustration (Zulfahmi B. Daulay, 2009)

Ignition

The ignition process is purposed to dried and then ignited the coal seem underground. This process is carried out with electric burning source and the initial fuel of sawdust that is added kerosene.

Gas Production

Syngas is produced through combustion and gasification reactions in three steps (oxidation, reduction, and pyrolysis). Combustion produces heat, carbon dioxide and some syngas (through partial combustion). Gasification reactions then take place, involving heat and carbon dioxide from combustion, pressure, steam and carbon from the coal. The syngas flows from the gasification zone, through constructed or formed horizontal channels, to the gas production well where it flows to the surface for treatment.

Decommisisioning

Once all the available coal has been extracted as a gaseous product, the gasification process is shut down according to known and demonstrated shut down procedures.

Characteristics and Site Selection of UCG

UCG need a characteristic and site selection to prevent uneffectively proccess. A developer have to considering the quality and quantity of syngas needed for a project's lifetime. Based on Vyas (2015) the UCG controlled by these aspects to decrease the critical issues.

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Geology

Some countries such as USA, UK, and Australia have developed their own criteria depending on local conditions. Hal yang paling difokuskan dalam aspek geologi untuk mempertimbangkan pemilihan site UCG adalah geography (topografi dan technological features of the area), geological structures (fault, fractures, fissures, etc), complete geological data of coal seam (include overburden and underburden).

Coal Composition

The amount of moisture, ash and sulphur can affect the quality of the gas. Ash content above 60% can inhibit the UCG proccess. Sulphur content can increase the impurities that should be cleaned. The moisture can inhibit the combustion proccess if its above 15%.

Coal Rank

The coal rank can be used to determine the quality of teh syngas. The lowest rank such as lignite and sub-bituminous coal are recommended for the UCG, because the low-rank of coals generally shrink when they burned, which increases the connections between the production and the injection wells.

Coal Porosity and Permeability

The porosity and Permeability of the coal seam can improve the flow of the syngas from the injection to production wells. It can be increased by the fracture while linking the injection to production wells with reverse combustion method.

Coal Seam Thicknes

The thickness of the coal should remain between 2 to 15 meters. Variations of thickness will complicate the drilling proccess if its more than 25% of thickness.

Coal Seam Angle (Dip)

The dip of coal seam should be between 0 to 70 degrees with less than 2 degrees of dip variation to avoid the drilling problems. The damage equipment and material will increase as high as the angle of dip.

Depth

The depth between 92 to 460 meters are recomended to do UCG proccess with preference the seams below 200 meters to avoid subsidence issues. Additionally, the impermeable rock should be more than 15 meters to prevent the subsidence and gas release. The aquifers above the coal seam should not be within 31 meters of the seam. The coal seam belom 460 meters potentially stop the gasification proccess because it can restricting the gas flow.

The Adventages of Underground Coal Gasification (UCG)

Underground Coal Gasification (UCG) have some advantages for underground coal resource utilization in environmental aspect and economic aspect. Base on UCG Association, the advantage on environmental aspect is there's nothing a pieces of coal lifted to surface. It is make environmental issues can reduce because if the combustion did on the surface will produce gas emissions such as CO_2, SO_2, NOx, HCN, SNO_3, H_2SO_4 directly. There several advantage including UCG produce less carbon residue than other methods gasification, low emission, more less ash production, low risk of surface water, no waste disposal and smaller surface footprints after projection.

The second aspect is economic aspect. Operating costs are lower than other methods, reducing rail/road infrastructure, low operational installation cost, syngas can distribute directly, low costs synthesis of liquid fuels, manufacture of chemicals such as ammonia and fertilizers, gasification takes place underground thereby reducing environmental management and associated costs. According Clean Coal Ltd. another advantage of UCG is for enhanced oil recovery (EOR) of mature oil fields (Clean Coal Ltd.).

Based on Pratiwi (2012) there is some comparison of Underground Coal Gasification to other coal technologies:

Comparison to Surface Mining

Surface mining exploits shallower coal seams usually less than 200 meter depth. To relatively high mining cost should be added the cost of field discharge, transportation, pollution cleanup, ash capture and storage.

Comparison to Underground Mining

Underground mining is used when coal seams are deeper, usually greater than depth of 1000 meters. This mining isn't performed in coal seams shallower than 50 meters in depth and doesn't exploit coal seams over 10m thick whereas opencast mines have no practical limit. (CCL).

Comparison to Surface Coal Gasification

According to CCL, surface gasification of coal has not yet been widely undertaken to date. In South Africa, where the practice is most common, coal is supplied from underground and opencast operations utilize any low cost and low quality bituminous coal.

Comparison to Coal Bed Methane (CBM)

Coal bed methane (CBM) is found in coals with a high methane content (generally over 10 m^3/t) and is best used in relatively shallow deposits where the reduced pressure improves the recoverability due to higher permeability within the coal seam. (Clean Coal Ltd.).

CONCLUSION

Underground Coal Gasification (UCG) is the gasification of coal in-situ, which is achieved by drilling boreholes into the coal and injecting water/air or water/oxygen mixtures. It is both an extraction process (like coal mining) and a conversion process (gasification) in one step, producing a high quality, affordable synthetic gas that can be processed to provide fuels for power generation, diesel fuels, jet fuels, hydrogen, fertilizers and chemical feed stocks.

The operating life of a UCG operation can be broadly broken down into four steps such as well construction, ignition, gas production, and decommissioning. The UCG process controlled by characteristic and site selection, so it has to be considered by geological aspect, composition, coal rank, coal porosity, permeability, thickness, dip and depth of the coal seam. The advantages of Underground Coal Gasification based on two aspects, environmental aspect and economic aspect. Based on that opportunities of UCG the Indonesian Government have to consider alternative energies which may be cheaper and cleaner unconventional energy. So this technology should be investigated for implementation in Indonesia.

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