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Syngas Characteristics from UCG Gasification Process with Lignite and Subbituminous Coal Types

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ABSTRACT

Underground Coal Gasification (UCG) is the process of converting the materials used to make synthetic gas in a feasible and economically attractive manner as a method for harnessing energy from underground coal sources. Coal gasification will produce a gas producer in the form of synthetic gas (syngas) with the main components consisting of carbon monoxide (CO), hydrogen (H_2), carbon dioxide (CO_2) and nitrogen (N_2) and low pollutants. The highest temperature produced with MT 47 lignite coal using an oxygen velocity of 5 liters/minute was 240^0 C at the 35th minute, while the lowest temperature was 95^0 C at the 95th minute. For Subbituminous AL 51 coal using an oxygen velocity of 5 liters/minute, the highest temperature is 354^0 C at 75 minutes, while the lowest temperature is 106^0 C at 130 minutes. At an oxygen velocity of 5 liters/minute the flash point / burn test is on the MT 47 lignite coal type in the 10th minute and at a temperature of 170^0 C. Meanwhile, the AL 51 subbituminous coal type is in the 30th minute and at a temperature of 313^0 C. Based on the discussion and analysis of data from the gasification test of lignite and subbituminous coal with variations in oxygen velocity of 5 liters/minute, the results obtained are that lignite coal burns faster (burn test) in the 10th minute at a temperature of 170^0 C, in the subbituminous type it has higher temperature 313^0 C and longer burn test at 30 minutes.

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1. INTRODUCTION

Indonesia as a country has various types of energy resources which are quite abundant [1]. Electrical energy is one of the basic needs of people everywhere. Both in developing countries such as Indonesia, as well as developed countries. The increasing demand for electrical energy in Indonesia is currently not balanced with the availability of electrical energy supply or the electrical energy crisis is something that cannot be avoided. [2]. The need for electrical energy in the world from year to year is increasing along with the development of human civilization. Meanwhile, the supply of electrical energy sourced from oil, natural gas, and coal has several limitations, including non-renewability, pollution, and environmental damage produced by these three energy sources in the short and long term. The increase in energy consumption in Indonesia encourages energy conservation in the field of renewable energy [3]. Renewable energy is non-fossil energy that can be renewed and managed properly. The limitations of fossil energy require

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diversification of energy sources to ensure the availability of sustainable energy leading to the intensification of renewable energy [4]. Therefore, sustainable renewable energy resources that can be classified as renewable energy are geothermal, hydro, solar, wind, biomass, marine, fuel cells, and nuclear [5]. On the other hand, electrical energy from renewable sources, such as solar, geothermal, wind, biomass, ocean currents, and waves has not been fully utilized. Indonesia has abundant new renewable energy potential, consisting of geothermal, hydro energy, wind energy, bioenergy (bioethanol, biodiesel, biomass), ocean current energy, nuclear energy, and solar energy which can be applied or utilized in almost every region in Indonesia. Indonesian [6].

Public awareness to pay more attention to the potential for new and renewable energy is needed in order to utilize the potentials of new and renewable energy from a small scale so that awareness will be fostered to protect the environment and contribute to sustainable development, and can support national energy security. Coal is the most rapidly growing energy source in the world in recent years - faster than gas, oil, nuclear, hydro and renewable energy, [7]. Utilization of coal energy sources is also increasing along with the decline in oil production. Coal is the most important energy source, widely used for electricity generation, and also serves as a basic energy source for the metal smelting, cement and other industries (metallurgy, textiles, pulp paper) [8]. Indonesia has a large potential for coal resources. Coal has the highest carbon content and impurities (sulfur, nitrogen and others). Coal releases gases (CO_2, N_2O, NOx, SOx and Hg) that cause global warming and pollution. Coal deposits in mines can also cause wastewater that has a high acidity level and has a high potential for pollution to the surrounding environment [9], but this can be solved by the electrocoagulation method [10]. Therefore, the use of clean and efficient coal is still a challenge that needs to be extensively pursued in order to extend the life of its availability. In addition to minimizing the global environmental burden, one way to increase the utilization of clean coal is through the coal gasification process. Gasification technology is a process of burning solid raw materials involving the reaction between oxygen, water vapor and carbon dioxide. The combustion products are reduced to flammable gases, such as carbon monoxide (CO), hydrogen (H_2) and methane (CH_4) [11].

Coal gasification will produce producer gas in the form of synthetic gas (syngas) with the main components consisting of carbon monoxide (CO), hydrogen (H_2), carbon dioxide (CO_2) and nitrogen (N_2) and low pollutants. So that energy experts have focused on developing coal gasification to meet future energy consumption. Coal suitable for UCG development is lignite to bituminous [12]. The deeper the coal seam, the higher the cost and risk of production if done using conventional methods, this gasification process is one method that can add to the economic value of coal [13]. Underground Coal Gasification (UCG) is a new technology that utilizes unmined coal, [14]. Some of the gas from the gasification can be used as fuel for power generation stations and some can be used as synthetic materials (syngas) for chemicals, such as hydrogen, methanol or other gaseous chemicals. UCG has advantages because it produces gas fuel that is more environmentally friendly in addition to utilizing subsurface coal which is currently uneconomical to mine. The development of this coal prototype is carried out to develop an underground coal gasification system, to produce the best quality syngas, and it is hoped that this UCG prototype will become a reference in future studies to increase coal syngas production.

2. RESEARCH METHOD

2.1 MATERIAL

Coal is a solid hydrocarbon fuel formed from plants in an oxygen-free environment which is influenced by long-lasting heat and pressure in nature with a complex composition [15]. In the industrial world associated with the combustion process and coal smelting, the main problem is to evaluate the properties of coal before using it. Until now in many power plants, chemical analysis methods used to obtain information about all parameters (proximate analysis, ultimate analysis, and calorific value) are very time consuming and require a lot of technical skills with detailed knowledge of coal chemistry testing [16]. In general, coal can be categorized based on water content, carbon content and calorific value as shown in Table 1 [17].

Table 1. Coal Category

Category	H_2O (%)	C (%)	Calorific (Kcal/kg)
Lignite	43,4	37,8	4113
Subbituminous	23,4	42,4	5403
Bituminous	11,6	54,2	7159
Anthracite	3,2	95,6	8027

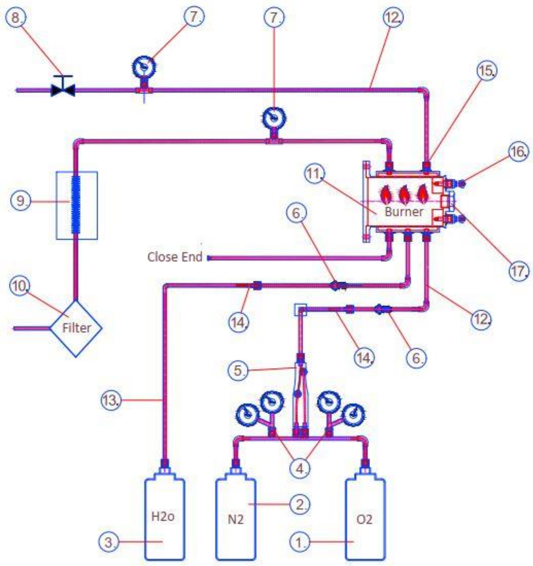

Figure 1. Underground Coal Gasification Prototype Design Schematic

Table 2 Description of UCG Prototype Components

No	Name Component	Qty	No	Keterangan	Qty
1	Oxygen Cylinder	1 Set	10	Filters	1 Set
2	Nitrogen Tubes	1 Set	11	Combution	1 Set
3	Tubes Air and Steam	1 Set	12	Tube	20 Meters
4	Regulators	2 Pcs	13	Hose	20 Meters
5	Gun Mixers	1 Set	14	Conector Hose	2 Pcs
6	Check Valve	2 Pcs	15	Conector Tube	2 Pcs
7	Pressure Gauge	2 Pcs	16	Glow Plug	4 Pcs
8	Gate Valve	2 Pcs	17	Plugs	1 Pcs
9	Coolers	1 Set			

Underground coal gasification is the process of in-situ coal gasification in coal seams deep underground by injection of compressed air through bore wells and producing coal fuel gas through production wells [18]. The UCG process involves the reaction of oxygen, air or steam with coal carbon and other pyrolysis products to produce syngas consisting mainly of methane, hydrogen, carbon monoxide, carbon dioxide and steam [19]. For example, hydrogen is a clean fuel that con stitutes a valuable chemical feedstock for different chemical processes and synthesis [20]. The resulting methane-rich syngas is compatible with natural gas and can be used as synthetic natural gas (SNG) for power generation, industrial feedstock or conversion to other fuels and chemicals [21]. In general, as a fuel, methane has high economic value as well as environmental, energy security and industrial safety benefits [22].

Underground coal gasification converts coal to gas while it is still in the coal seam (in-situ). Gas is produced and extracted through wells drilled into the coal seam. The well, in this case the injection, is used to supply oxidants (air, oxygen and nitrogen) and steam to ignite and refuel the underground combustion process. Separate production wells are used to bring product gas to the surface. High-pressure combustion is carried out at 700–900° C (1,290–1,650° F), but can reach up to 1,500° C (2,730° F). The process decomposes coal and produces carbon dioxide (CO_2), hydrogen (H_2), carbon monoxide (CO) and methane (CH_4). In addition, small amounts of contaminants including sulfur oxide (SOx), mono-nitrogen oxide (NOx), and hydrogen sulfide (H_2S) are produced. It is necessary to monitor the temperature in the combustion chamber system to maintain stability [23]. Syngas production through gasification of low quality coal, which in Indonesia reaches 70% [24]-[27] will be able to increase the selling price of the coal.

Syngas from coal gasification has good prospects for three reasons, first, syngas products are very commercial, widely used by industries, both for chemicals, energy, and transportation fuels. Second, syngas is more environmentally friendly than natural gas or petroleum with low CO_2, SOx, and NOx emissions. Third, the abundance of coal resources in Indonesia. In addition to its large reserves, coal gasification can also utilize lignite coal, which in Indonesia reaches 70% [24]. So that the coal gasification process will produce synthetic gas (syngas) with the main components consisting of carbon monoxide (CO), hydrogen (H_2), and (CH_4) [25]. Different amounts of hydrocarbons in the syngas, at different exit temperatures, use different ratios of steam and oxygen to coal feed [26][30]. In this case, in the syngas content the amount of hydrocarbons will be different, the temperature that comes out will be different too and this is influenced by the feed or oxygen that is flowed into the combustion chamber or combustion.

3. RESULTS AND DISCUSSION

Each type of coal has a different composition. Proxymite coal content testing is needed to determine the character and composition of the coal, physically, chemically and fuel properties of the coal that will be used in the gasification process. Proxymite analysis of coal type MT 47 and AL 51 which shows the content of moister, folate mater, ash and fixcarbon in the coal. This sampling was carried out in the laboratory of the Coal Transport Handling work unit of PT. Bukit Asam.

Table 3. Coal Proximite Analysis MT 47 and AL 51

Proximate Analysis	MT 47	AL 51
Seam	A1	A1
Kalori (kcal/kg, ar)	4700	5300
Moisture (%, abd)	14.68	10.35
Ash Content (%, abd)	5.3	17.02
Volatile Matter (%, abd)	40.58	35.58
Fixed Carbon (%, abd)	39.45	37.05

The ultimate test of coal content is needed to determine the character and composition of the coal, physically, chemically and fuel properties of the coal that will be used in the gasification process. The ultimate analysis of the MT 47 and AL 51 coal types which shows the content of Carbon, Hydrogen, Sulfur, Nitrogen and Oxygen in the coal. This sampling was carried out in the laboratory of the Coal Transport Handling work unit of PT. Bukit Asam.

Table 4. Coal Ultimate Analysis MT 47 and AL 51

Ultimate Analysis	MT 47	AL 51
Seam	A1	A1
Kalori (kcal/kg, ar)	4700	5300
Carbon (%, abd)	60.66	54.71
Hydrogen (%, abd)	4.39	5.27
Nitrogen (%, abd)	0.69	0.81
Sulfur (%, abd)	1.03	0.68
Oxygen (%, abd)	13.26	21.54

Figure 2 explains that the highest temperature produced with MT 47 lignite coal uses an oxygen velocity of 5 liters/minute.

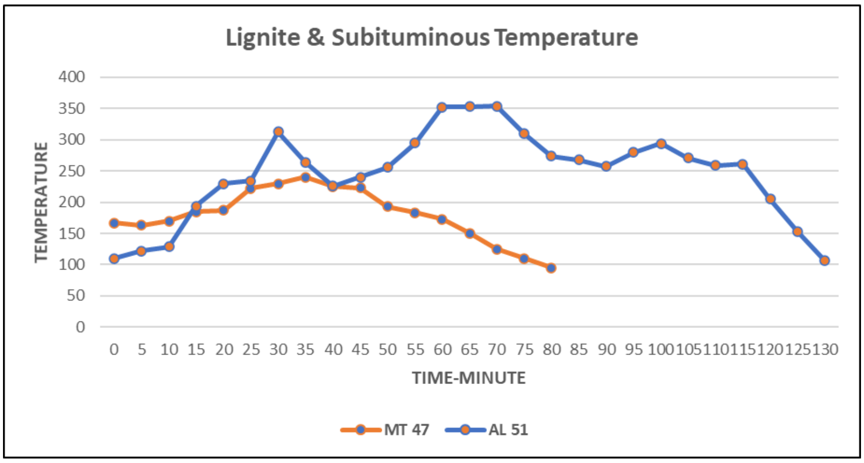

Figure 2. Temperature with oxygen speed 5 Liter/Minute

Figure 2 explains that, the highest temperature produced with MT 47 lignite coal using an oxygen velocity of 5 liters/minute is 240^0 C at the 35th minute, while the lowest temperature is 95^0 C at the 80th minute. For Subbituminous AL 51 coal using an oxygen velocity of 5 liters/minute, the highest temperature is 354^0 C at 70 minutes, while the lowest temperature is 106^0 C at 130 minutes.

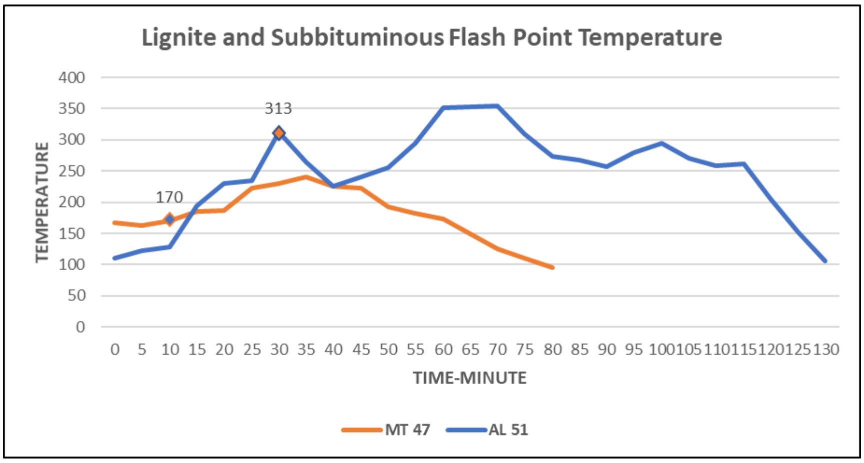

Figure 3. Flash point test / burn test.

Figure 3 explains that, at an oxygen velocity of 5 liters/minute, the flash point / burn test is for lignite coal type MT 47 in the 10th minute and at a temperature of 170^0 C. Meanwhile, for the subbituminous coal type AL 51 in the 30th minute and at a temperature of 313^0 C. This means that by using lignite coal, it burns faster (burning test) but the subbituminous type has a higher temperature.

4. CONCLUSION

Based on the discussion and analysis of data from gasification tests for lignite and subbituminous coal with variations in oxygen velocity of 5 liters/minute, it can be concluded that the type of lignite coal burns faster (burn test) in the 20th minute at a temperature of 318.5^0 C. Subbituminous has a higher temperature of 460^0 C and a longer burn test at 30 minutes.

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