Vol. 1 No. 2 (2021): IJRVOCAS - August

IJRVOCAS covers all topics of VET-related research from pre-vocational education (PVE), initial vocational education and training (IVET) and career and technical education (CTE) to workforce education (WE), human resource development (HRD), professional education and training (PET) and continuing vocational education and training (CVET).

Publication frequency

- Issues (online): triannually (April, August, December) plus special issues.

DOI: https://doi.org/10.53893/ijrvocas.v1i2
Published: 2021-09-02

Articles

International Journal of Research in Vocational Studies (IJRVOCAS)
Vol. 1, No. 2, August 2021
Print ISSN 2777-0168 | Online ISSN 2777-0141 | DOI prefix: 10.53893

Effect of Oxygen Flow Rate on Combustion Time and Temperature of Underground Coal Gasification

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Article Info

Article history:

Received July 11, 2021
Revised August 10, 2021
Accepted August 20, 2021

Keywords:

Coal
Underground Coal Gasification
Flow Rate
Temperature
Effective Flame

ABSTRACT

Underground Coal Gasification (UCG) is a process of converting coal in the ground into synthetic gas that has economic value. In the UCG process which will be carried out in the UCG prototype assisted by the presence of oxygen as a gasification agent, which this gasification agent will help the process of burning coal in the ground. The flow rate of oxygen in the process of UCG affecting the coal combustion temperature and effective flame from burning coal. The highest temperature at a flow rate of 5 l/min is 240°C, at an oxygen flow rate of 3 l/min the highest temperature is 143°C and at an oxygen flow rate of 2 l/min the highest temperature is 135°C and time effective flame at a flow rate of 5 l/min ie 80 minutes, effective burning time on the speed of the flow rate of 3 l/min ie for 120 minutes and time effective flame at a flow rate of 2 l/min ie for 165 minutes. This study proves that the greater the oxygen flow rate is used as the gasification agent at UCG process the lignite coal combustion temperatures will be high and effective flame coal combustion process will be more brief.

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1. INTRODUCTION

Increased energy consumption in Indonesia encourages energy conservation in the field of renewable energy [1]. So that renewable energy becomes one of the options for future energy needs as renewable alternative energy that can support the energy needs of people who still rely on fossil energy sources, one of which is coal. This is supported by the fact that coal is an important energy source for the world, which is used to generate electricity that can generate nearly 40% of the world's electricity [2]. While Indonesia has coal reserves of as much as 61 274 billion tons of which 70% are brown coal (lignite) [3], but the abundant coal reserves in the future will be reduced [4]. The use of fossil energy such as coal has environmental impacts that must be considered, as does global warming [5], and coal mine wastewater which has a high enough potential to pollute the environment [6], however, coal water waste can be solved by electrocoagulation [7]. The existence of fossil energy is limited and has the potential to pollute the environment, needs to be verified as an energy source with the aim of ensuring the availability of clean energy, and the right direction is renewable energy [8].

Many states are developing new and renewable energy, one that would change the quality of coal has a higher sales value, by doing downstream coal with coal gasification methods. In Indonesia, the downstream of coal has been confirmed in law number 3 of 2020, namely the mineral and coal law, especially in article 102 paragraph 1 requiring an increase in mineral and coal added value, which reads “IUP or IUPK holders at the stage of Production Operation activities are required to increase the added value of Minerals in Mining business activities through: a) Processing and Purification for metal mineral mining commodities, b) Processing for non-metal mineral mining commodities, and c) processing for rock mining commodities” [9].

The program is planned to downstream coal gasification method. According to Aida Syarif et al, what is meant by coal gasification is the process of converting coal solids into a synthetic gas mixture that contains fuel [10]. The gasification process still has the potential to make the process of mining, it obviously still requires huge production costs if all calculated starting from the mine explore, the mining process, and downstream processes. Not to mention if the early stages of mining are done, then the potential of environmental destruction will continue to happen, so it still harms the environment and surrounding mines.

One of the downstream processes of coal that are currently being developed in the world is Underground Coal Gasification (UCG). UCG is a new technology that utilizes non-mined coal [11], can provide significant benefits compared to conventional coal mining [12], because UCG is a clean coal gasification technology to safely take advantage of deep coal seams and turn it into a synthetic gas [13]. In addition, UCG is also an alternative gasification technique that is used to exploit chemical energy from coal reserves [14]. Various articles and studies show that UCG is technically feasible and economically attractive as a method to harness energy from coal sources [15]. Economically UCG is a cost-effective and environmentally friendly clean coal technology that converts coal in-situ into combustible gas [16]. Development of underground coal gasification as a need-based business, effectively exploiting coal resources in a clean manner and reducing the tight supply of natural gas in the global industry competition [17]. But in practice, UCG trial preparation in mining operations still need to ensure the safety and stability of the process [18], since the UCG process affects the surrounding rock movement and deformation around the combustion chamber area, the vertical stress distribution of the coal pillar and subsidence [19]. As a clean coal gasification technology, the UCG process with several types of coal will not produce coke around the combustion chamber area [19]. So the underground coal gasification process can be carried out stably [20].

The gasification process that will be carried out in the UCG prototype is assisted by an injection hole, which will help the combustion process in the soilThe injection condition is one of the key parameters to control the product gas quality in the UCG process [21]. The UCG process involves the reaction of oxygen, air or steam with coal carbon and pyrolysis products [14], because oxygen affects the temperature and pressure in the coal gasification process [13]. The higher the oxygen flow rate during the lignite coal gasification process, the higher gasification efficiency is indicated by the increase in reaction temperature and the expansion of the gasification area [21]. However, if there is a decrease in the combustion air flow rate, it will tend to make the combustion temperature smaller which will make the temperature smaller so that the efficiency will also decrease.

One of the things that will be considered in this study the temperature. The high temperature generated during the underground gasification process will not only produce high-temperature thermal stresses around the rock from the combustion area but also change the physical and mechanical parameters of the surrounding rock [22]. The high temperature generated during the underground gasification process will not only produce high-temperature thermal stresses around the rock from the combustion area but also change the physical and mechanical parameters of the surrounding rock [22].

2. RESEARCH METHOD

In this section, we will discuss the material to be used in the UCG research, namely MT 47 coal obtained from the Bukit Asam Tanjung Enim mine site, and discuss the research method used, namely the process of burning coal in the prototype underground coal gasification.

2.1 MATERIAL

The coal used in this study is a type of lignite with 4700 calories taken from the Muara Tiga Besar (MTB) mine site of PT Bukit Asam at the coordinates of 3º43'16,315"LS, 103º42'30,463", with mine brand MT 47 (4600 – 4800 kcal/kg, ar). A study showed that Underground Coal Gasification with lignite coal using oxygen as a gasification agent may be a viable option as it results in an overall energy efficiency of the process estimated at 59% [23].

Grains of coal used in this study are in-situ grain. In-Situ coal gasification using oxygen is an alternative technique for gasification. In the coal samples which have been taken from the front, will be formed in accordance with the dimensions of the gasification combustion chamber, the length of 18 cm and a diameter of 12.5 cm by three samples of in-situ with an average weight of 2.2 kg. The purpose of the establishment of the coal sample is to provide an overview of the prototype model of UCG coal conditions at the time were in the layer below the ground.

2.2 RESEARCH METHOD

This research will be carried out using a prototype Underground Coal Gasification (UCG) with a length of 21 cm and a diameter of 13 cm. UCG prototype is expected to produce syngas. The process carried out at the beginning is making a UCG prototype. The gasification agent included is oxygen (O_2), because it can maintain the gasification process [24]. Oxygen as a gasification agent is injected into the UCG prototype to increase the calorific value and gas production rate [25]. The oxygen will pass through a inch pipe fed into the coal seam or combustion chamber. The flow rate of oxygen as a gasification agent will be varied, namely 2 l/min, 3 l/min, and 5l/min, the flow rate of the gasification agent will be regulated using an analog regulator, and each distribution pipe will be given a valve. Aims to determine the ratio between the flow rates.

The impact of different percentage of each gasification agent will certainly have different temperature values. The temperature in the combustion chamber is one of the variables in the combustion process [26]. To determine the temperature of UCG during the combustion stage concerning time studied using a thermocouple [27]. The temperature obtained in the UCG process describes the spread of gasification with the maximum temperature that is expected to be measurable in the coal seam during gasification. [28]. Then the need for monitoring the temperature in the combustion chamber system to maintain stability [29]. Such monitoring is useful for maintaining a safe and efficient UCG [30].

During the combustion process, the gas will pass through the output hole on the prototype. The syngas output hole is only installed one hole using a heat-resistant pipe with a diameter of inch. The process of releasing the gas will go through a cooling bath which is useful for lowering high gas temperatures, then headed to the gas filter for filtering so that the gas cleaner and last through the gas towards the shelter. 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). [31].

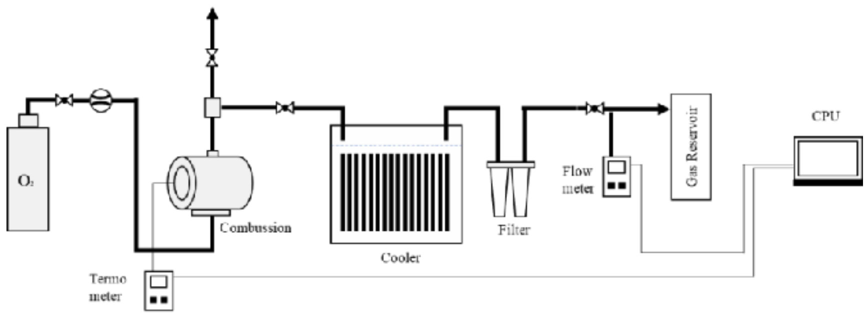

Figure 1. Schematic of Prototype Underground Coal Gasification

3. RESULTS AND DISCUSSION

This paper discusses the characteristics of the combustion rate in the Underground Coal Gasification process, with discussion materials namely the characteristics of the MT 47 coal sample, combustion temperature and effective flame.

3.1 Coal Sample Characteristics

Each type of coal has a different composition. So it is necessary to test the coal content by proxymite 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. Proximate analysis of the MT 47 coal type will show the moister content, ash content, volatile meter and fixed carbon in the coal, as shown in table 1. This sampling analysis was carried out at the PT Bukit Asam Penanganan Angkutan Batubara (PAB) work unit laboratory.

Table 1. Proximate Anailysis

Coal MT 47	
Calori (kkal/kg, ar)	4700
Moisture (%, abd)	14,68
Ash Content (%, abd)	5,3
Volatile Matter (%, abd)	40,58
Fixed Carbon (%, abd)	39,45

The proximate testing process of MT 47 liginite coal seen in table 1 is known to have lignite coal calories of 4700 kcal/kg, moisture 14.68%, Ash Content 5.3%, volatile metter 50.58% and fixed carbon 39.45%.

After conducting proximate testing, an ultimate coal content test is carried out 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 coal type will show the content of Carbon, Hydrogen, Sulfur, Nitrogen, and Oxygen in the coal as table 2 below. This sampling analysis was carried out at the PT Bukit Asam Penanganan Angkutan Batubara (PAB) work unit laboratory.

Table 2. Ultimate Anailysis

Analysis Ultimate Batubara MT 47	
Calori (kkal/kg, ar)	4700
Carbon (%adb)	60,66
Hydrogen (%adb)	4,39
Nitrogen (%adb)	0,69
Sulfur (%adb)	1,03
Oxygen (%adb)	13,26

The ultimate testing process for MT 47 lignite coal seen in table 2 is known to have Carbon 60.66%, Hydrogen 4.39%, Nitrogen 0.69%, Sulfur 1.03%, and Oxygen 13.26%.

3.2 Temperature

The underground coal gasification process will be seen as the difference in combustion temperature with different combustion oxygen rates, namely 2 l/min, 3 l/min, and 5 l/min. The difference in oxygen flow produces different temperatures, so the temperature will be studied and monitored through a thermometer that appears on the computer every 5 minutes of burning. The thermometer is connected to the thermocouple in the combustion chamber. The temperature results obtained from this study are depicted in a graph which can be seen in Figure 2 below.

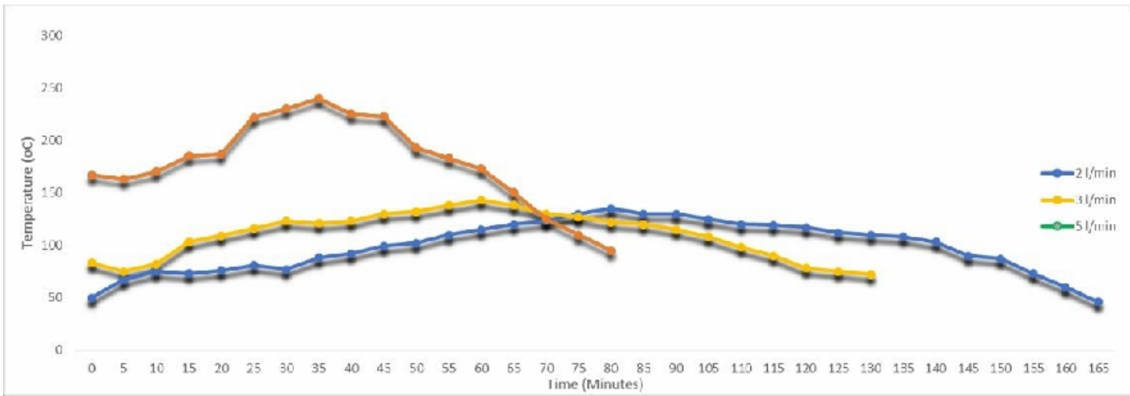

Figure 2. Underground Coal Gasification Combustion Temperature Graph

The temperature graph shown in figure 2 explains that high temperatures generated by using an oxygen flow rate of 2 l/min are 135ºC in the 80th minute, and the lowest temperature is 46ºC at 165 minutes, From the 120th minute to the 165th minute, the temperature decreased due to the burning of MT 47 lignite coal in the UCG prototype has been exhausted. Then, when the oxygen flow rate of 3 l/min generate high temperature namely 143ºC in the 60th minute, while the lowest temperature generated by 72ºC the 120th minute. In the 95th minute to the 120th minute, the temperature decreased due to the burning of MT 47 lignite coal in the UCG prototype has been exhausted. Then the high temperature at the time of the oxygen flow rate of 5 L / min is 240ºC in the 35th minute, while the lowest temperature was 95ºC at the 80th minute. From the 60th minute to the 95th minute, the temperature decreased, due to the burning of lignite coal in the prototype MT 47 UCG has been exhausted.

It can be seen that among other flow rates, the oxygen flow rate of 5 l/min produces the highest temperature, which is 240ºC. So it can be ascertained that the higher the combustion flow rate as a gasification agent in UCG, the higher the combustion temperature.

3.3 Effective Flame

In the underground coal gasification process, the combustion time will be monitored through a stopwatch every minute with different combustion oxygen rates, namely 2 l/min, 3 l/min, and 5 l/min. The difference in oxygen flow has a different combustion time. The results of the combustion time obtained from this study are depicted in a graph which can be seen in Figure 3 below.

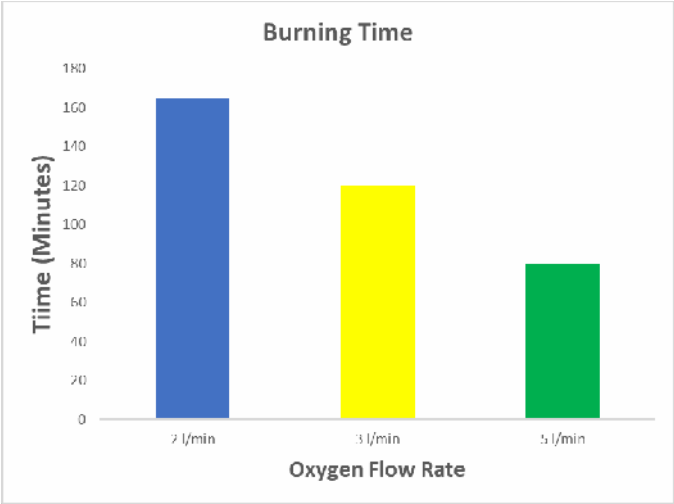

Figure 3. Underground Coal Gasification Burning Time

The burning time graph shown in figure 3 it can be seen that the flow rate of 2 l/min has an effective flame time of 165 minutes, a flow rate of 3 l/min has an effective flame time of 120 minutes and a flow rate of 5 l/min has an effective flame time of 80 minutes.

Based on the research data above, the high temperature at an oxygen flow rate of 2 l/min is 135ºC at the 80th minute, at an oxygen flow rate of 3 l/min the resulting high temperature is 143ºC at the 60th minute and a high temperature at a flow rate of 5 l/min is 240ºC. So it can be stated that the largest air flow rate (5 l/min) produces the highest temperature and has a shorter effective ignition time while using a lower flow rate of 2 l/min has the highest temperature of only 135ºC and has a longer effective ignition time.

4. CONCLUSION

Research carried out proved that the greater the oxygen flow rate is used as the gasification agent at the UCG process the lignite coal combustion temperatures will be high and the effective flame coal combustion process will be briefer. It can be proven by the following data:

1. The combustion temperature is influenced by variations in the oxygen flow rate, the highest temperature at a flow rate of 5 l/min is 240ºC, at an oxygen flow rate of 3 l/min the highest temperature is 143ºC, and at an oxygen flow rate of 2 l/min, the highest temperature is 135ºC.
2. Burning time effectively is also influenced by variations in the flow rate of oxygen, burning time effectively at a flow rate of 5 l/min i.e. 80 minutes, burning time effective at a flow rate of 3 l/min ie for 120 minutes, and burning time effectively at a flow rate of 2 l/min i.e. for 165 minutes.

ACKNOWLEDGEMENTS

The authors would like to thank Yaysan Bukit Asam, Head of the Study Program, Head of the Chemical Laboratory and staff of the Politeknik Negeri Sriwijaya, General Manager of UPTE and the Senior Managers and Managers of PT Bukit Asam who have supported this research.

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