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Production of CO Gas as Fuel through the Utilization of CO_2 Greenhouse Gas and Fine Coal Solid Waste

Syukran Yazila[1], Muhammad Faizal[2], David Bahrin[2], Novia Novia[2], Muhammad Said[3]

[1] Enviromental Engineering Study Program, Sriwijaya University, Jl. Padang Selasa No. 524, Palembang, 30139, Indonesia
[2] Chemical Engineering Department, Faculty of Engineering, Sriwijaya University, Jl. Raya Palembang Prabumulih Km 32 Indralaya, Ogan Ilir, Sumatera Selatan, 30662, Indonesia.
[3] Chemistry Department, Faculty of Mathematics and Natural Science, Universitas Sriwijaya, Jl. Raya Palembang Prabumulih Km 32 Indralaya, Ogan Ilir, Sumatera Selatan 30662, Indonesia

[*]*Corresponding Author: syukranyazila128@yahoo.com*

Abstract

Utilization of fine coal gasified with CO_2 (carbon dioxide) gas to produce CO (carbon monoxide) fuel is one effort to utilize coal waste and CO_2 greenhouse gas emissions. Testing was carried out at the Sriwijaya University Laboratory in Palembang with the aim of analyzing the production process of CO gas as fuel by utilizing the greenhouse gas CO_2 through the gasification of fine coal solid waste and knowing and analyzing the influence of temperature, reaction time, and CO_2 gas decrease on the Boundouard reaction on gas yields of CO and CO_2. The initial stage is to prepare 2.3 kg of fine coal, and the grain size has been filtered to a size of < 3 mm or mesh 8–18, then heated to a temperature of 500 ˚C with a time of 68 minutes and 48 seconds for the carbonization process. Fine coal that has been carbonized is then reacted with CO_2 gas in a heating furnace at variable temperatures of 300, 400, 450, and 500 ˚C, respectively, and at a flow rate of 2.5; 5; 7.5; 10; and 15 L/min, respectively. From 26 test samples, it shows that the best variable for producing CO gas is heating at a temperature of 500 ˚C with a CO_2 reactor gas discharge of 5 L/min, which can produce CO gas with a concentration of 208,586 ppm and CO_2 gas at 357,703 ppm with a CO and CO_2 ratio of 0.583.

Keywords: Fine coal, Carbon Dioxide, Carbonization, Carbon Monoxide.

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Abstrak (Indonesian)

Pemanfaatan Batubara Halus yang digasifikasi dengan gas CO_2 (Karbon Dioksida) untuk menghasilkan bahan bakar CO (Karbon Monoksida) merupakan salah satu upaya pemanfaatan limbah batubara dan pemanfaatan emisi gas rumah kaca CO_2. Pengujian dilakukan di Laboratorium Universitas Sriwijaya Palembang dengan tujuan untuk menganalisis proses produksi gas CO sebagai bahan bakar dengan memanfaatkan gas rumah kaca CO_2 melalui gasifikasi limbah padat batubara halus serta mengetahui dan menganalisis pengaruh suhu, waktu reaksi dan penurunan gas CO_2 pada reaksi Boundouard terhadap hasil gas CO dan CO_2. Tahap awal menyiapkan 2,3 kg batubara halus dan ukuran butirannya telah disaring dengan ukuran < 3 mm atau atau mesh 8–18 kemudian dipanaskan pada suhu 500˚C dengan waktu 68 menit 48 detik untuk proses karbonisasi. Batubara halus yang telah dikarbonisasi kemudian direaksikan dengan gas CO_2 dalam tungku pemanas dengan variabel suhu masing-masing 300, 400, 450, dan 500˚C dan pada laju alir masing-masing 2,5; 5; 7,5; 10; dan 15 L/menit. Dari 26 sampel pengujian menunjukkan bahwa variabel terbaik untuk menghasilkan gas CO adalah pemanasan pada suhu 500 ˚C dengan debit gas reaktor CO_2 sebesar 5 L/menit yang dapat menghasilkan gas CO dengan konsentrasi 208,586 ppm dan gas CO_2. adalah 357,703 ppm dengan Rasio CO & CO_2 adalah 0,583.

Kata Kunci: Batubara halus, Karbondioksida, Karbonisasi, Karbon Monoksida

INTRODUCTION

Indonesia has abundant coal-related natural resources. Data from the Ministry of Energy and Mineral Resources (EMR) through a press release on January 15, 2024, recorded that Indonesia's coal production during 2023 reached 775 million tons, with 30% domestic consumption and 70% exports [1]. Domestic coal consumption is still dominated by steam power plants (PLTU). The contribution of state revenue from PNBP and coal royalties until December 11, 2023, reached IDR 94.59 trillion and became the largest compared to other mineral commodities such as gold and copper. However, the use of coal has caused an increase in greenhouse gases in the atmosphere, especially CO_2 [2].

Fine coal is coal waste that arises from the coal production process in the form of fine coal. The amount of fine coal, according to the Ministry of Energy and Mineral Resources, will reach 183 million tons in 2023, and every year the number continues to increase along with the increase in coal production capacity, so its existence must be utilized. Processing is difficult because it contains a lot of ash, sulfur, and water, so the cost of processing fine coal increases compared to processing coarse coal. The industry prefers to dispose of fine coal as waste in the sedimentation pond [3].

The use of fine coal to produce CO gas gasified with CO_2 gas is one of the efforts in the context of utilizing fine coal waste and utilizing CO_2 gas emissions into useful products [4]. The gasification from carbonization in question is the process of converting fine coal as a solid material into a mixture of CO fuel gas with CO_2 gas as a reactor. Gasification will give rise to CO_2 gas, hydrogen gas (H_2), methane gas (CH_4), and nitrogen gas (N_2) [5]. Carbonization will cause the decomposition of organic materials and raw materials and the release of impurities. Most of the non-carbon elements will be lost. As it carbonizes, the initial pore structure will change [6]. Coal gasification is the process of converting solid coal into a mixture of gases. Coal gasification begins with a pyrolysis process, followed by a gasification process. The pyrolysis process begins to occur at a temperature of 400°C [7]. A gasification medium that can be used as a gasifying agent is air, steam, CO_2, H_2, or a mixture of these mediums. Gasification of coal with CO_2 gas medium produces the main product in the form of CO gas [8]. The main reaction that occurs is the Boudouard reaction.:

$$C(s)+CO_2(g) \rightarrow 2CO(g)\ \Delta H^{o}_{R}= +172\ kJ/mol\ ....(1)$$

Previous research from Azis et al. [9] found that the quality of fine coal after washing with the molenization method became better, but the utilization of fine coal waste requires high handling costs. Then Faizal et al. [10] researched the purification of syngas from carbon dioxide (CO_2) and the gasification content of fine coal. But with and without the absorption of hydrated calcium monoxide (CaO) up to $Ca(OH)_2$ and researching the increase in hydrogen gas (H_2) in syngas. Andican et al. [11] analyzed the utilization of coal waste into syngas through catalytic gasification, where the process is It is carried out by using natural zeolite as a catalyst to increase the CO content in syngas. Syngas composition and quality parameters are evaluated through the H_2/CO ratio, calorific value, and gasification efficiency. The H_2/CO ratio of syngas makes fine coal very suitable for use as a raw material for the gasification process to produce environmentally friendly syngas [12].

Sobah [13] analyzed the utilization of coal through the CO_2 gasification process. However, this research aims to determine the effect of adding $Ca(OH)_2$ in the pyrolysis process on the gasification results of bituminous coal using CO_2 gas as a medium. The research results show that coal gasification with the addition of $Ca(OH)_2$ in the pyrolysis process has an influence on the composition of the resulting gas, namely decreasing CO_2 gas content and decreasing sulfur content in coal pyrolysis and gasification. The large amount of research and development on energy from combustion exhaust as well as the small amount of research on the utility of CO_2 gas to produce CO gas as an energy source is the driving force behind the research discussed in this paper to move Indonesia towards becoming a pioneer in a clean, pollution-free, and environmentally friendly country. Based on this, research was carried out on the production of co-gas as fuel through the utilization of CO_2 greenhouse gases and fine coal solid waste.

MATERIALS AND METHODS

Materials

The fine coal test material used as a sample was obtained from the stock of fine coal ex of the Central Banko line of PT Bukit Asam Tbk. Tanjung Enim with the type of Sub Bituminus coal. The grain size is made uniform to a size of < 3 mm, or mesh 8–18. The required fine coal material is 2.3 kg. Then CO_2 gas is added to a 25-kilogram cylinder complete with a regulator valve. Water and ice cubes are in various coolers in the condenser.

Testing Tools

The tools used in this study include an electric furnace or electric heating stove with a capacity of 5 liters, complete with valves, pipeline pipes, temperature indicators, condensers, CO gas meters, CO_2 gas meters, urine tubes for storing test gas, 5 kg of plastic for test gas steamers, wind pumps, and stationery for documentation. Make sure the electrical system for the furnace, including temperature monitoring, is working properly, and then connect the CO_2 gas hose to the heating room. The scheme of these testing tools is described in **Figure** 1.

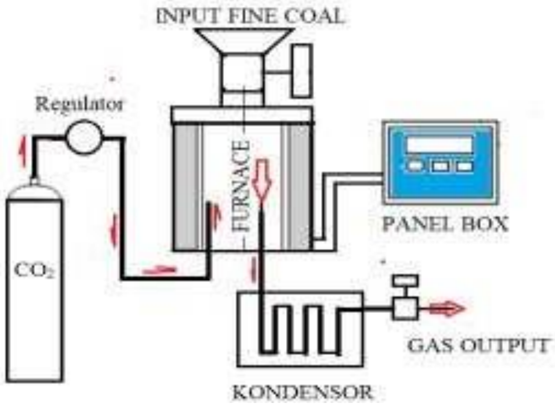

Figure 1. Scheme of testing Tools combine with reactor

Procedure and Data Analysis

Before the test, the fine coal is carbonized first by putting it in a closed furnace. The amount of fine coal used is 2.3 kg and heated to a temperature of 500 °C. Then it is cooled first, and then it is continued with heating tests using CO_2 gas as a reactor. Sampling was carried out in accordance with the measurement matrix with several temperature variables, including at temperatures of 300, 400, 450, and 500 °C, and several CO_2 gas flow input discharges of 2.5; 5; 7.5; 10; and 15 L/min.

The gas sample tested is stored in a urine bag. Sample testing is carried out in a sealed bag. There are several gases that arise from fine coal gasification that has been carbonized with CO_2 gas, including CO gas, CO_2 gas, hydrogen gas (H_2), methane gas (CH_4), and nitrogen (N_2), but what will be detected is limited to CO and CO_2 gas. In the first test this time, it turned out that the CO and CO_2 concentration values after gasification were exceeding the measurement standards of measuring instrument equipment, so it needs to be done with a comparison of the concentration in the measuring medium. The measuring medium on 5 kg of plastic filled with a measured volume of air is 8,876 liters and tightly closed with plastic sealing. CO and CO_2 measuring devices have been inserted into the measuring medium before. To measure the concentration of the formed gas, a gas sample of 20 or 30 mL is inserted with a syringe pump. The measurement of the gas concentration that was detected was determined using equation (2) and (3):

$$KCO = \frac{KR}{VS} \, x \, KA \ldots \quad (2)$$

$$KCO_2 = \frac{VR}{VS} \, x \, KA \ldots \quad (3)$$

Information:

KCO = CO gas concentration
VR = Volume of the measuring chamber
VS = Sample gas volume
KA = Final Gas Concentration
KCO_2 = CO_2 gas concentration

RESULTS AND DISCUSSION

Temperature greatly influences CO gas production during pyrolysis. In theory, the higher the temperature used, the more gas will be formed. The use of a furnace and determining the optimal temperature were carried out to determine the optimal conditions for carbonization carried out on fine coal so that it could be continued to vary the CO_2 rate in this research. The results of the optimal determination of fine coal carbonization can be seen in **Figure** 2.

Figure 2 shows that the maximum temperature for the carbonization of fine coal was 500˚C. The initial stage is to heat the fine coal in the heating furnace to a temperature of 500 °C as a carbonization process to remove the content of impurity gases [13]. Impure gas from the combustion of fine coal can cause the formation of other undesirable compounds, so that the formation of CO gas is not optimal [14]. This optimum result is also in accordance with research conducted by Faizal et al. [15], which states that the optimum carbonization result for fine coal and a mixture of both with biomass is around 500˚C. The rise in temperature in this carbonization makes the reaction of H_2 and CO formation an endothermic reaction, so that with a higher temperature, the reaction will lead to the formation of the purity product [16]. The research continued with the production of CO from burning fine coal mixed with CO_2. This combustion produces CO gas which functions as fuel. CO gas can be converted for various needs as low-carbon fuel for ships, trucks, buses and trains [17].

In this research, the optimum CO_2 gas flow conditions were carried out with several variations with the optimum variation results obtained respectively at a temperature of 500˚C, namely 208,586 ppm (5 L/min), 10,651 ppm (7.55 L/min), 2,840 ppm (10 L /min) and 5,148 ppm (15 L/min). The graph of production CO in 5 variation of CO_2 flow rate can be seen in **Figure** 3.

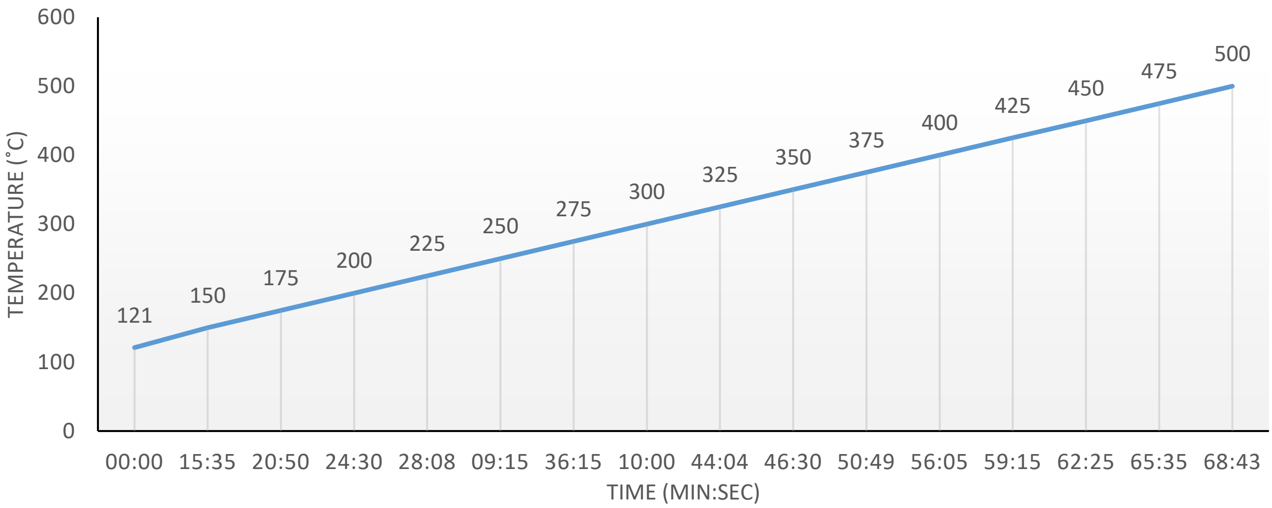

Figure 2. Graph of temperature and time in carbonization of fine coal

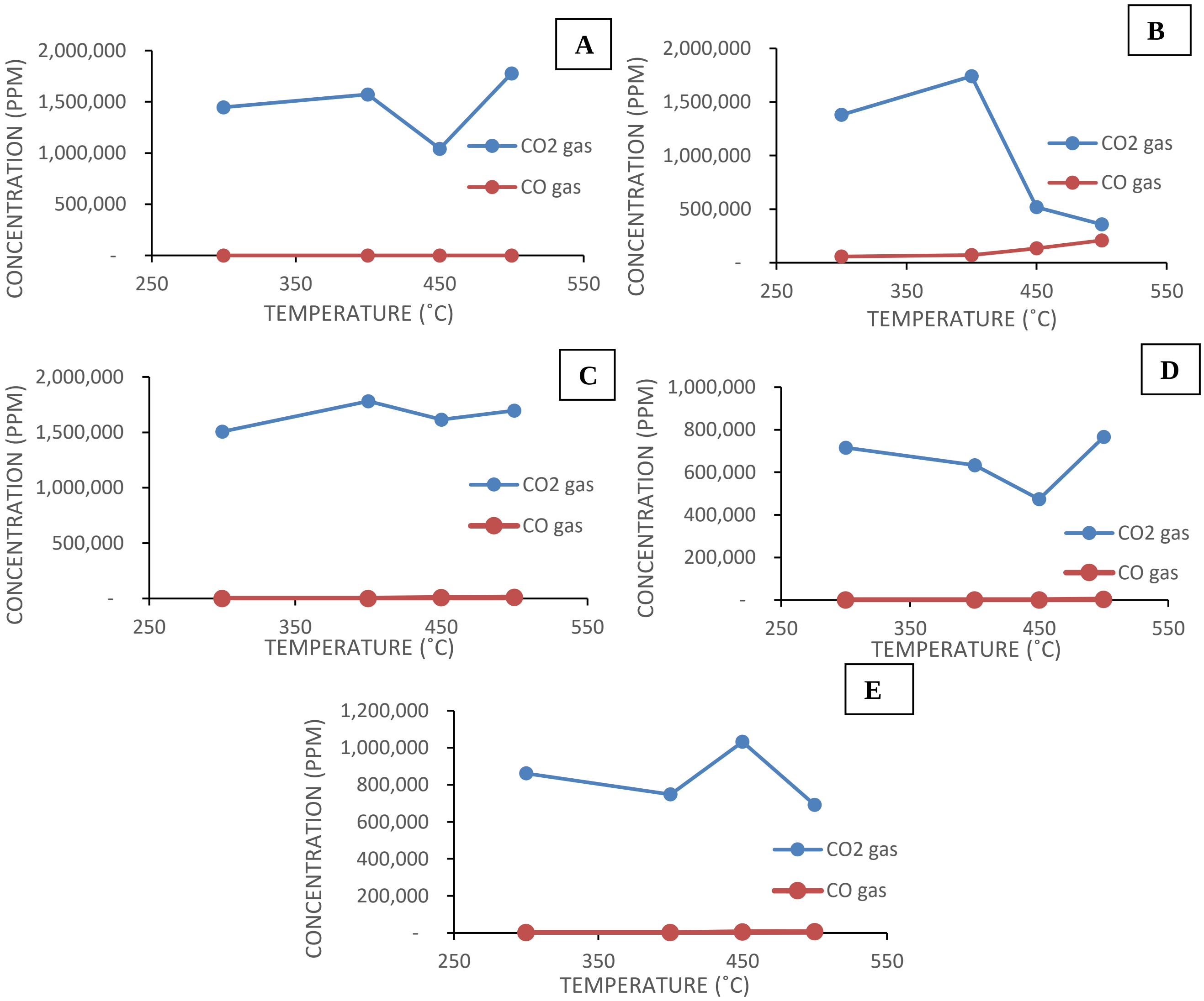

Figure 3. Production of CO and CO_2 in variation flow rate of CO_2 (A) 2.5 L/min ; (B) 5 L/min ; (C) 7.5 L/min ; (D) 10 L/min, and (E) 15 L/min.

The optimum variation is 5 L/min, which produces 208,586 ppm of CO gas and 357,703 ppm of CO_2 content. In variation flow rate of 5 L/min, CO_2 content decreases at temperature 500 ˚C. This indicates the success of CO_2 being converted into CO in accordance with the Boudouard reaction, which states that the reaction to form CO from the reaction between a carbon source and CO_2 gas produces an exothermic reaction [18]. At the CO_2 flow rate variation of 2.5 L/min, no CO gas is formed. That was because the CO_2 gas that is flowed does not saturate the air during carbonization in the reactor, so the reaction focuses on the formation of CO_2 [19], which is marked by increasing levels of CO_2 gas in graph (A) at temperatures ranging from 300 to 500˚C. At variations above the CO_2 flow rate of 5 L/min, the formation of CO gas is not optimal. This was predicted by researchers due to the supersaturation of CO_2 gas in the reactor tube, thus stabilizing the reaction thermally during carbonization. The ratio of CO/CO_2 for production from the optimum variation of temperature and flow rate CO_2 is 0.583. This result shows a significant conversion of CO_2 to CO using carbonization from fine coal, where the greater the value of the CO/CO_2 ratio, the better the method for optimizing the production of CO gas [20]. The research concluded that optimal CO production ultimately aims to reduce the use of pure raw materials, alleviate the energy crisis, and reduce CO_2 emissions into the atmosphere [21].

CONCLUSION

From the research that has been carried out, it can be concluded that fine coal as coal waste and CO_2 gas as an emission gas can be used as carbon monoxide (CO) gas. The formation of CO gas from the gasification of fine coal with the CO_2 reactor corresponds to the conversion of the Boudouard reaction. The highest concentration of CO gas is at a variable temperature of 500 ˚C with a CO_2 gas flow rate of 5 L/min, which is 208,586 ppm; the CO_2 that appears is 357,703 ppm. The ratio of CO/CO_2 is 0.583.

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