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Effect of Absorbent for Gas Purification Unit in Biomass Gasification Process with Downdraft Method

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Abstract. The development of industry causes energy needs to increase. So that fossil energy reserves are increasingly depleting. This resulted in the growth of various alternative energies. One alternative energy that is being developed is biomass-based energy. Biomass is a renewable energy source that comes from plants both directly and indirectly. Indonesia is a country with a tropical climate that has a very large biomass potential. One of the methods that can be used in processing biomass is gasification, which is a process to convert solid biomass raw materials into fuels (syngas). The problem from the gasification process is the syngas produced has a low purity level. This is because there are still impurities that are contained in syngas. Therefore, a purification unit is needed in the gasification device. This research aims to make absorbents that can be used in gasification purification units. The types of absorbent used is coconut shell activated carbon. The pore structure of carbon is characterized by using an N₂-sorption analyzer (Nova 2000, Quantachrome). Based on the results of characterization, it can be seen that the specific surface area of activated carbon absorbent from the coconut shell is 1320 m²/gram with an average pore diameter of 1.82 nm. The experiment device mainly consisted of gasification reactor, filter, and blower. The gasification reactor was installed to heating the biomass with the supply oxygen. The reactor had a height of 170 cm and a diameter of 50 cm in which the bagasse with the capacity of 15 kg/h was quickly burned. The gas filter contains the absorbent to clean the syngas product. The absorbent was installed in upper four holes. The blower was used to suck up the syngas. Some thermocouple and gas indicator were installed to monitor the condition in the system. The syngas production was analyzed by the GC/MS analysis. The effect of absorbent is to improve the syngas composition such as CO, H₂, and CH₄. The syngas contents in our experiment were CO, CH₄, and H₂ with a percentage of 9.294%, 1.348%, and 7.773%, respectively. These results are better than the previous research with the syngas contents are 7.891% of CO, 0.100% of CH₄, and 0.889% of H₂ because the previous research was not equipped the absorbent.

Keywords: Absorbent; Activated Carbon; Biomass; Gasification



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1. Introduction

Along with economic growth, population, development and national development cause energy demand from year to year to increase in all sectors. So far, national energy needs are met by non-renewable energy resources, such as natural gas, petroleum, coal and so on. However, fossil energy reserves are increasingly depleting and there will be an energy crisis if the energy is completely depleted. The depletion of energy reserves is forcing the Indonesian government and society to look for other alternatives as an energy source.

Indonesia is a tropical country, so it has huge biomass potential. Agriculture and plantation industries such as oil palm plantations, coconut plantations, sugar cane plantations, industrial timber plantations, and other types, produce a lot of biomass waste. The development of biomass energy sources underwent many changes. Combustion is the main method for converting biomass into energy, but along with the development of science and technology has changed the application of biomass to become more modern. The process of gasification converts biomass into gas, pyrolysis (converts biomass into charcoal), anaerobic decomposition, and briquette are processes that can convert biomass into energy [1].

Biomass gasification equipment using imperfect combustion in the room so that it can withstand high temperatures is called a gasifier. So that incomplete combustion can occur, then air with a small amount of stoichiometric needs of combustion is flowed into the reactor to supply oxygen needs using a fan/blower. The combustion process that occurs causes a thermo-chemical reaction that produces CO, H₂, and methane gas (CH₄) [2].

One of the treatments that can be used in processing biomass is gasification which is a process for converting solid biomass raw material into gas fuel (syngas). Gasification is defined as the thermo-chemical conversion of carbon-based solid or liquid materials (feedstock) into combustible gas products with a supply of gasification aids in the form of other gases [3]. Thermo-chemical conversion changes the chemical structure of biomass at high temperatures. Gasification aids encourage carbon-based materials to be converted quickly into gas through various heterogeneous reactions [3][4].

The gasification unit consists of two types of updraft and downdraft. This type of updraft, which experiences a counter-current flow between gas and solid material, is more suitable for the conversion of char (char) which is less reactive to gas. Nearly 90% of the world's coal is classified using this configuration [4][5].

While the type of downdraft experiences a concurrent flow between the solid material being fed and the gas, which is less flexible for water content and size. However, this type of downdraft is preferred for small scale processes because it provides cleaner gas yields and results in uncomplicated cleaning or purification processes [6].

Currently, a lot of researchers have focused on syngas production and tar removal. These are important in the gasification process. Herman, *et al* [7] reported that the gasification process was used catalyst potential such as dolomite, nickel, and olivine to improve the gas quality. Al-Rahbi, *et al* [8] investigated that gasification process was used tire char as the filter to reduce the tar production. Peng, *et al* [9] reported that the improvement the syngas production was used metal catalyst with two varying temperature and residence time. De Diego, *et al* [10] was investigated that biomass gasification to produce clean gas was used hot catalytic filter candles.

However, there was not the experiment to improve the syngas production from gasification by using water scrubber and activated carbon absorbent. Hence, in this work, the main objective is the gasification process from bagasse with water scrubber and activated carbon absorbent for clean syngas production. The water scrubber was set to catch some tars as the by-product that is called the vapor cracking process. The water scrubber was equipped with the water about two liters to spray itself when the vapor through the water scrubber. The filtered gas equipped the activated carbon absorbent to clean the syngas product. Furthermore, the syngas production was analyzed by GCMS.

2. Method

2.1 Experiment Material

The experiment material in this work includes bagasse, wood charcoal, and activated carbon as an absorbent. The bagasse were taken from Sugar Factory Madukismo, Yogyakarta, Indonesia. To make the uniform size and the consistent feeding, bagasse as raw material was crushed with the size of 2-4 cm in particle size. Before input in the system, the bagasse was dried under the sunshine to reduce the water content. The wood charcoal was used as the thermal carrier to start up the combustion process in the reactor. Activated carbon as the filter gas to clean the syngas was installed.

2.2 Experiment Method

The experiment method comprised three main steps, such as biomass preparation, gasification process, and syngas analysis. Firstly, consider the biomass preparation, the bagasse was dried under the sunshine to reduce the water content about 25%, preparing the charcoal that has blazng, installing the thermocouple and gas indicator. Secondly, the gasification process was carried bagasse feedstock out on 3000 gr. The blower was sucked for flowing the air as supply oxygen into gasifier and burning biomass comes out through a hole in the gasification reactor. Every minute the temperature varying was recorded during the gasification process. Thirdly, consider a syngas analysis, the syngas samples were taken in the three positions using tube vacuum to check the gas composition by GCMS analysis. The final result of gasification was tried to light a fire on syngas results with the help of a match and record the time. If the combustible gas can ignite, then it can be interpreted that the syngas starts. During the combustion process, tar as a by-product of combustion is caught/collected in the water scrubber. After the combustion process is complete, ash or residual combustion is weighed. Activated carbon was installed in the inside filter gas unit to know the characterization of syngas. The gasification unit mainly consisted of a gasification reactor, water scrubber, filter, and blower. The syngas production was analyzed by the GC/MS analysis.

3. Result and Discussion

3.1. Characterization Absorbent

The structure of coconut shell porous carbon which includes specific surface area, average pore diameter, and pore volume are presented in Table 1. The table shows that commercial porous carbon from coconut shells is micropore carbon (IUPAC classification) with an average diameter of 1.82 nm. Furthermore, it can be seen from the surface area and micropore volume that is more dominant than the surface area and mesoporous volume, which is 92%. Besides, Table 1 also provides information that the pore structure of a coconut shell porous carbon is a micropore carbon (classification of IUPAC) with a specific surface area of coconut shell porous carbon which is equal to 1320 m²/gram.

Table 1. Characteristics of Coconut Shell Activated Carbon

Characteristic	Value
Specific surface area (S_{BET}), m ² /gram	1320
Micropore area (S_{mic}), m ² /gram	1220
% S_{mic}	92
Total pore volume, cm ³ /gram	0.60
Micropore volume (V_{mic}), cm ³ /gram	0.45
% V_{mic}	75
Average pore diameter, nm	1.82

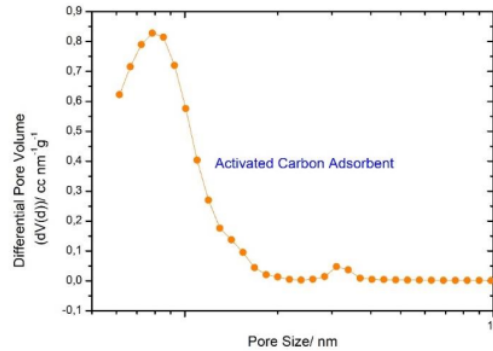


Figure 1. Pore Size Distribution with QSDFT-N₂ Model

11 Pore size distribution is calculated using the Quenched Solid State Functional Theory (QSDFT) model. In Figure 1, it can be seen that the pore distribution with a size below 2 nm is very dominant and there are two dominant peaks, which are at 0.8 nm and 2.8 nm. Based on the results of the pore distribution, it is further strengthened that the porous carbon biomass is microporous carbon (IUPAC classification). The adsorbent pore size is one of the factors that affect the absorption capacity. The smaller the pore size, the contact surface area in the absorption process will be even greater [11]. This shows that the type of adsorbent used is activated carbon with a type of micropore pore size that has a large absorption capacity.

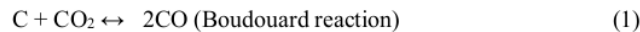
15 3.2. The Effect of Adsorbent on Syngas Properties

Fig 2 shows the analysis of syngas on gasification from bagasse using water scrubber and activated carbon adsorbent. The syngas properties were tested by gas chromatograph. The effect of water scrubber and activated carbon adsorbent is to improve the syngas composition such as CO, H₂ and CH₄. According to [12] the important of syngas content is CO, H₂, CH₄, and CO₂. Therefore, the testing of gas chromatograph show that the syngas properties from our experiment consist of CO, H₂, CH₄, and CO₂. These results were combined with the previous research that was displayed in Table 2.

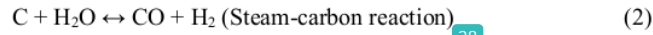
Table. 2 The Correlation of Syngas Properties

Content	Previous research	This study
CO	√	√
CO ₂	√	√
H ₂	√	√

The highest content was CO in syngas gasification due to the reaction of syngas formation has influenced by two reactions namely Boudouard reaction and steam-carbon reaction. Firstly, the Boudouard reaction comes from the reaction between carbon in bagasse with carbon monoxide which produces high CO in the syngas gasification. The reaction Boudouard shows in the exp.1.



Secondly, the steam-carbon reaction is almost similar to the Boudouard reaction. However, the steam-carbon reaction is not only the carbon forming reaction but also hydrogen (H₂) forming reaction. The steam reaction shows in the exp.2.



The formation of Hydrogen (H₂) syngas has influenced by the water-gas reaction shift. In this reaction, the carbon monoxide (CO) was shaped like in the exp 3.

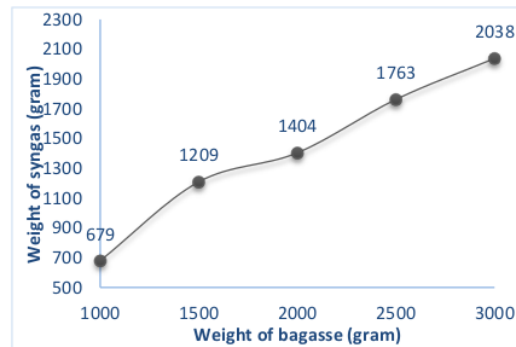
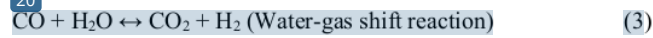


Figure 2. The Influence of the Amount of Bagasse on Syngas Burning Time

Fig 3 shown that these results are better than the previous research [13] with the syngas contents are 7.891% of CO, 0.100% of CH₄, and 0.889% of H₂ because the previous research was not equipped the water scrubber and activated carbon. The increasing of syngas content is influenced by reducing the sampling product (TAR) in the reaction zone when the hot gas through the water scrubber and activated carbon without leaving TAR in the system. The water scrubber was installed with a content of water (H₂O) that has operated as the vapor cracking process due to water in the scrubber can evaporate with the help of hot gas output from the gasification reactor and can catch the tar product. In addition, the activated carbon was put in the filter gas as the filter the gas from water scrubber.

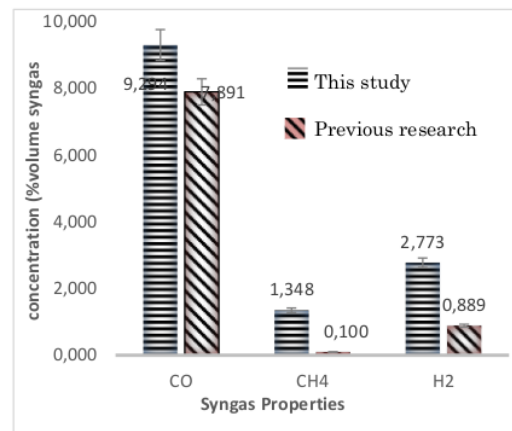


Figure 3. The Gas Content of Syngas on Gasification of Bagasse

4. Conclusion

Activated carbon can be trapped the TAR as the sampling product. The syngas production has improved by using the water scrubber and activated carbon when compared with previous research. The syngas properties were included CO, CH₄, and H₂ with the percentages 9.294%, 1.348%, and 7.773%, respectively. The activated carbon can provide the tar reduction reaction and can accelerate the tar reduction reaction.

Acknowledgment

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