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Experimental Study of Updraft Gasification of Rice Husk and Coal to Produce Syngas

Limited resource of fossil fuel inspires many research activities to search for alternative energy. This work offers alternative solution to address this problem through charcoal gasification. The goal of this research is to find the amount of syngas produced in the gasification process. The alternative fuel was produced from the mixing rice husk and low quality coal due to their abundant resource in South Kalimantan. The mixture was then gasified at 500 °C. The highest syngas volume at 29.56 L was in the sample of SP 200 gr and BB 0 then followed at 25.7 L for ratio SP 180 gr : BB 20 gr. The lowest produced syngas 19.45 was produced from the sample with ratio SP 100 gr : BB 100 gr. This gasification process also resulted in side product, i.e. tar component which varies from 22.5 mL to 58.75 mL.

Keywords: Alternative Energy, Gasification, Updraft, Rice Husk, Coal

1. INTRODUCTION

Consumption rate of fossil energy in Indonesia is still relatively high, i.e. 96% which comes from 48% for crude oil, 30% for coal, and natural gas for 18%. In this case, to suppress the consumption rate we need to utilize the renewable energy but the realization is still not according as planned. Low quality coal contain lower calorific value than other quality coal and high water rate, that is why low quality coal only used domestically for electrical needs [1]. Biomass is renewable energy that has huge potential. Biomass is an organic material from renewable energy, one of the organic materials is rice husk. Rice husk is easy to found and sold for cheap price in market. South Borneo is one of the provinces that produce a lot of rice national wide and the first in Borneo Island. South Borneo's production is around 2.140.276 ton from 511.213 ha rice field [2].

Gasification is a process to convert solid material in biomass into gas fuel or chemical raw gas material (syngas) which is often called gasification [3]. The gasification process is a process to convert carbon-containing materials into combustible gases. Gasification requires basic ingredients containing hydrocarbons such as biomass and coal. In the furnace the heating process occurs to a certain reaction temperature and the gasification process will then produce combustible gases and by products in the form of tar and char. In gasification, synthetic gas (syngas) will be produced with different composition, ratio and characteristics of the gas depending on the raw material, process and type of gasifier used [4]. Solid biomass can be converted into combustible gas, this process requires additional materials to drive chemical reactions in the gasification process. This material is called a gasification agent, the main content of this material is oxygen, CO₂ is applied to the mixture and N₂. In air only oxygen is able to react because oxygen can generate heat and this increase in oxygen will help reduce the amount of syngas [3].

Gasification type

Gasification is divided into two based on the direction of gas flow, i.e. updraft and downdraft gasification.

a. Updraft Gasification

In updraft gasification the direction of air flow from the blower is from the bottom of the furnace [3]. Nitrogen gas enters through the bottom of the furnace to push oxygen out of the furnace where no combustion process will occur. Any gas which can actively involve in combustion burning should be removed from the furnace and flow out from top of the gasifier. Meanwhile the by products from the gasification process, i.e. ash, falls to the bottom of the gasifier due to the gravitational force. The combustible gas moves towards the top of the gasifier which has lower temperature than other parts of gasifier. A small scale application is the advantage of

updraft gasification. Additionally, the charcoal produced is small since it is carried by the gas upwards. Disadvantage of the gasifier type is high mass of tar.

Figure 1. Updraft gasification scheme [3]

b. Downdraft Gasification

Air will enter the downward gasifier through the top of the furnace. In this type of gasification gas nitrogen enters through the top of the gasifier to push oxygen out of the furnace to prevent any combustion inside the gasifier. Dirtier produced gas is the disadvantage of downdraft gasification than the updraft type since the char will also be carried out by the gas. Additionally, ash that comes out along with the gas is difficult to control.

Figure 2. Downdraft Gasification Scheme [3]

Processes in gasification reactors

Gasification is chemical decomposition process at high temperatures to obtain energy from hydrocarbons. This process requires combustion process at very limited amount of air. In the gasification process hydrocarbon molecules having long and complicated chains will be broken down into smaller and simpler molecules in the form of gas. The by products in the gasification process are tar and charcoal. Tar is resulted from the condensation of gas coming out of the furnace while the charcoal is solid waste of base material. In part, the gas obtained from the gasification process will come out from the gasification furnace and still contains water.

Condensation process is then required to clean the produced syngas.

a. Drying Process

In the drying zone the biomass is dried by utilizing heat energy from the sun before the biomass is fed into the gasifier reactor. In solid fuels there is a water content, this water content can be reduced by utilizing the material and air that enters the furnace. In the process of drying organic acids will be evaporated. Temperature in this zone ranges from 100-250°C.

b. Pyrolysis Process

Pyrolysis process is a combustion process without involving oxygen, resulting in an incomplete combustion process. Biomass will form gas, tar and char which occur in the pyrolysis process. The process of pyrolysis takes place around a temperature of 300°C in the process of pyrolysis the resulting product is Biomass Char + Tar + Gas (CO₂; CO; H₂O; H₂; CH₄)

c. Reduction Process

The char content produced in the pyrolysis process does not fully contain carbon, there is also the content of chemical compounds such as hydrogen and oxygen. For this reason, to produce combustible gases such as hydrogen and carbon monoxide, the char must be reacted with carbon dioxide. In the process of reduction occurs at temperatures of 400°C-1000°C and gas that can burn only CO, H₂ and CH₄ begins to form.

d. Oxidation process

The combustion process will oxidize the hydrogen and carbon content contained in the fuel by an exothermic reaction, while the gases produced from the endothermic process will be reduced. The combustion process is the most important process in gasifiers, because in this combustion process will form the heat energy needed in endothermic reactions. In this process heat, light, N₂ and other gases (SO₂, CO, NO₂, etc.) will be produced. To do a combustion reaction, there are three important elements which complement each other, namely heat, fuel and air. The combustion process consists of two types, namely incomplete combustion and perfect combustion. Incomplete combustion occurs when the element C contained in the material reacts with O₂ and the gas produced is entirely CO₂, whereas complete combustion occurs when all elements of C that react with O₂ only produce CO₂, all elements of H produce H₂O and all S produces SO₂. Temperatures in this zone range from 700-1500°C

Biomass

Biomass is a biological material with a carbon structure and is composed of a chemical mixture containing nitrogen, oxygen, hydrogen and other elements. Biomass is a renewable resource. Rice husk if used as a gasification feed has some certain advantages because the water content is quite low and the size is uniform. Rice husk also has a low mass density of 122 kg/m³ and a solid mass density of 500 kg/m³. The results of proximate and ultimate analysis for rice husks are shown in the table below.

Table 1 Proximate Analysis and Rice Husk ultimates

Proximate analysis		Ultimate Analysis	
Component	% Mass	Component	% Mass
Volatil	57.06	Hydrogen	5.59
Permanent carbon	15.58	carbon	34.92
Ash	19.52	sulfur	0.08
Water	7.84	Nytrogen	0.34
		Oxygen	39.55
		Ash	19.52
		LHV, kJ/kg	14.807

The rice husk contained lignin of 23.16%, cellulose 32.69% and hemicellulose 43.86% (Eni, 2015). In the process of gasification of rice husk will pass the drying process at a temperature of 60°C - 134°C so that the water content in the rice husk will decrease. Decomposition of the chemical structure in the rice husk is first stage until the temperature reaches 341°C, where hemicellulose is degraded which causes volatile vapors, so that the aliphatic chain breaks and removes the wax content.

Coal

Coal is known as "black gold", people recognize it as a combustible black stone, coal geochemists, believe coal is a sedimentary rock which is chemically and physically heterogeneous containing carbon, hydrocarbon,

hydrogen, and oxygen as the main component components and sulfur and nitrogen as additional elements. Coal classification consists of commercial aspects and scientific aspects. Classification of coal for scientific purposes includes, among other things, Ganesha coal and its ranks, while commercial needs include trade value and utilization. In general the classification of coal in Indonesia is divided into brown coal and hard coal (SNI 13-6011-1999, 1999). Brown coal (low energy coal) is the lowest rank type of coal, is soft, easy to squeeze, contains high water (10-70%), and it consists of soft brown coal and lignitic or hard brown coal. The calorific value <7,000 calories/gram (dry ash free-ASTM 388-1984). Hard coal is defined as all types of coal which have a higher rank than brown coal, are harder, not easily squeezed, compact, contain relatively low water content, generally wood structures are no longer visible, and are relatively resistant to physical damage when handling. The calorific value > 7,000 heat/gram (dry ash free-ASTM 388-1984).

Table 2 Element composition and heating value of various types of coal

Composition of Elements of Several Types of Coal					
Coal Type	Mass Percentage				
	% C	% H	% O	% H ₂ O	Volatile Matter %
Lignit	60-70	5-6	20-30	50-70	45 -55
Subbituminous	75-80	5-6	15-20	25-30	40 -45
Bituminous	80-90	4-5	10-15	5-10	20 -40
Antrasit	90-95	2-3	2-3	2-5	5-7

2. RESEARCH METHODS

In this study using the type of updraft gasification, the installation of gasification equipment in this study can be seen in Figure 3 and the material in this study using biomass of rice husk and low quality coal (*subbituminous*). The composition of the mixture of materials between rice husk and coal is sample A 200 gram rice husk and 0 gram coal, in sample B 180 gram rice husk and 20 gram coal, in sample C 140 gram rice husk and 60 gram coal and in sample D 100 gram rice husk and 100 gram coal.

1. Thermocontroller
2. Thermocouple
3. Data logger
4. Furnace
5. Heater
6. Laptop
7. Erlemeyer Tube
8. Flow meter
9. Urine Bag

Figure 3. Gasification equipment installation

Testing stages

Mix the ingredients between rice husk and coal in a container then stir evenly between the rice husk and coal, put the material into the furnace, low quality rice husk and coal which we are ready to put into the gasification furnace, after all the installation is installed perfectly put in the low quality coal and rice husk into the gasification stove, after that close the top of the stove and check again if there is a leak in the stove. After

making sure there is no leakage, turn on the switch on the thermocontroler and simultaneously run the data logger. Record the temperature during the course of the gasification process and the heater temperature every 5 minutes and record the volume of gas produced every 50 cm³ increase. If the temperature has reached 500°C, keep that temperature constant and make sure there is no leakage. Then record the total output of gas, tar and char formed

3. RESULTS AND DISCUSSION

Research data taken in the form of heating rate data, data on the relationship of temperature to time, syngas volume results data and byproduct data in the form of char and tar.

Figure 5 Correlation between temperature and time for 200 gram rice husks and 0 gram coal

Figure 5 shows a graph of the relationship of temperature to time, where the initial temperature of heating 27°C is then heated to 120 minutes. On the graph variation of 200 gram rice husk mixture material: 0 gram coal with increasing time the temperature increases and the time needed to reach a temperature of 500°C is 42 minutes. Then the temperature fluctuates until the time reaches 120 minutes.

Figure 6 Graph of the relationship of temperature to time in 180 grams of rice husk and 20 grams of coal

Figure 6 shows a graph of the relationship of temperature to time, where the initial temperature of heating 27°C is then heated to 120 minutes. In the variation curve of 180 gram rice husk mixture material: 20 gram coal with increasing time, the temperature also increases, the time required to reach a temperature of 500°C is 36 minutes.

Then the temperature fluctuates until the time reaches 120 minutes.

Figure 7 Graph of the relationship of temperature to time in 140 gr rice husks and 60 gr coal

Figure 7 shows a graph of the relationship of temperature to time, where the initial temperature of heating 27°C is then heated to 120 minutes. On the graph variation of the mixture of 140 gram rice husks: 60 gram coal with increasing time the temperature increases, the time required to reach a temperature of 500°C is 39.33°C / minute. Then the temperature fluctuates until the time reaches 120 minutes.

Figure 8 Graph of the relationship of temperature to time in 100 gram rice husks and 100 gram coal

Figure 8 shows a graph of the relationship of temperature to time, where the initial heating temperature of 27°C is then heated to 120 minutes. On the graph variation of rice husk mixed ingredients 100 gram : 100 gram coal with increasing time the temperature increases, the time required to reach a temperature of 500 °C is 11.82 °C/minute. Then the temperature fluctuates until the time reaches 120 minutes.

Figure 9 Graphs of rice husk and coal gas volumes for all mixture variations

In figure 9 shows the volume of gas produced is greater in 200 gram rice husk: 0 gram coal at 29.56 L, 180 gram rice husk: 20 gram coal at 25.7 L, 140 gram rice husk: 60 gram coal at 21.88 L, for 100 gram rice husk: 100 gram coal for 19.45 L

Figure 10 Graphs of rice husk and coal Tar results for all variables.

In Figure 10 Graph of results of rice husk and coal Tar on all variables and Figure 11 Graph of results of rice husk Char all variables are by-products produced from the gasification process. The largest Tar is produced on a 200 gram rice husk sample : 0 grams of coal as much as 58.75 milli liters and the largest Char produced is on a rice husk sample 140 : 60 grams coal as much as 117 grams.

Figure 11 Graphs of Char yields of rice husks and coal on all variables

4. CONCLUSIONS

Based on the discussion and analysis of data from the aim of low quality rice husk and coal gasification with a variation of rice husk 200 gram: coal 0 gram, rice husk 180 gram coal 20 gram, rice husk 140 gram: coal 60 gram and rice husk 100 gram coal 100 gram can be concluded as following:

1. Total syngas results obtained in the gasification process of rice husk and coal low-quality updraft that is as much as 96.62 L. The most volume in the rice husk 200 gram sample : coal 0 gram amounted to 29.56 L, the rice husk sample 180 gram : coal 20 gram at 25.7 L, at rice husk 140 gram : coal 60 gram at 21.88 L and the least volume at rice husk 100 gr : coal 100 gram at 19.45L.
2. The results of byproduct gasification of rice husk and low quality coal updraft obtained the highest Tar results on the rice husk 200 gram : coal 0 gram as much as 58.75 ml, on the rice husk 180 gram : coal 20 gram produced as much as 45 ml, on the sample rice husk 140 gram of coal 60 gram is produced 32.5 ml and on the sample rice husk 100 gram : coal 100 gram is produced as much as 22.5 ml.

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