STUDY OF CHARACTERISTICS OF GASIFICATION PROCESS OF VARIOUS BIOMASS IN A DOWNDRAFT GASIFIER

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Abstract

Biomass gasification is an endothermic reaction process for converting biomass into syngas, occurs at high temperatures with limited oxygen. Knowing the temperature profile of biomass gasification wood charcoal, coconut shell charcoal and coconut shell, rice husk and woodchip and seek optimal results from gasification of biomass are the purpose of the research.

The equipment in this research consisted of; gasifier as the main tool with 4 temperature sensors, two cyclones for tar and dust separator, cooler to refrigerate and filter containing biomass as a catcher of dust and tar from the syngas. Research start by ignite the biomass in the gasifier, the air flows by blower and the syngas came out after the filter. Research variabel are variation of biomass types mentioned above and variation of shell and coconut shell charcoal mixing. Observations were made up until the biomass in the gasifier did not produce syngas, characterized by gas results could not burn.

The results of the temperature profile of gasification of various types of biomass shows that the syngas appeared in the early minutes (2 minutes until the 5th) on the gasification, such as gasification coconut shell, woodchip, rice husk. Syngas of coconut shell charcoal is 2,825% w/w of biomass and can burn for 19 minutes and resulted in 1,92% ash and 29,57% charcoal. Syngas of mixture 25% shell and 75% coconut shell charcoal is 5,013% w/w of biomass and can burn for 30 minutes and resulted in 1,61% ash and 5,1% charcoal.

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1. Introduction

Energy sources available in Indonesia, apart from petroleum, still a lot of potential to be extracted and used in the form of renewable energy sources. Along with the increasing global issues of the environment (eg, global warming), the utilization of renewable energy sources that provide a more environmentally friendly are alternative to the fulfillment of the national energy supply (Pratoto dan Raharjo, 2008).

Concern for the problems over the release of a policy to encourage the reduction of fossil fuel consumption and increased use of renewable energy as outlined in the form of targeted national primary energy mix in 2025 (PP No. 5 of 2006). One of the efforts to fullfill the targets of the national energy mix is promoting the use of biomass as an energy source (Yulistiani, 2009).

Gasification is a thermal process, where heating biomass in a low oxygen environment to convert solid biomass or other carbonaceous solids into a synthetic gas which flammable. Gasification or pyrolysis products are distributed as a solid product (char), liquids and gases (mainly hydrogen and carbon monoxide) (Tsai et. al., 2006). Amount and distribution of each product can be set according to the expected destination, which in this case operating conditions are very influential. higher the temperature, smaller the amount of solids and the large amount of liquid product (Tsai et. al., 2006). Through gasification process, we can change almost all of the solid organic material into a clean fuel gas, the neutral and the best way to take advantage of biomass gasification is to produce either electricity or heat.

2. Metodology

Tools and Materials Research

The tools used in this study are; downdraft gasifier with a capacity of 0.03 m^3 of biomass, which is coupled with two cyclone, cooler (gas cooler) and the syngas filter, as shown in Figure 1. Digital scales for weighing the biomass fuel, biomass ash and unburned after the gasification process.

Materials used are; rice husk, wood chips, wood charcoal, coconut shell charcoal and coconut shell.

Research Procedure

The biomass gasification research begins with preparing the raw material by means of drying biomass feedstock in the direct sun light followed by size reduction of raw materials into 2 or 4 cm (for the material wood and coconut shell charcoal). Scale the biomass by using a digital balance.

Biomass gasification begins by entering the biomass feedstock into the gasifier. Turning on the blower to draw air into the gasifier. Ignite the biomass through the combustion hole. Record the temperature change per minute during the gasification process takes place.

The end result is a gas of gasification coming out of the blower, tar housed in 2 pieces cyclones and ash mixed with charcoal were held under the gasification reactor. The mixture of ash and charcoal sieved using a 2 mm diameter sieve and finer ash can be separated from the charcoal then weighed and the weight recorded.

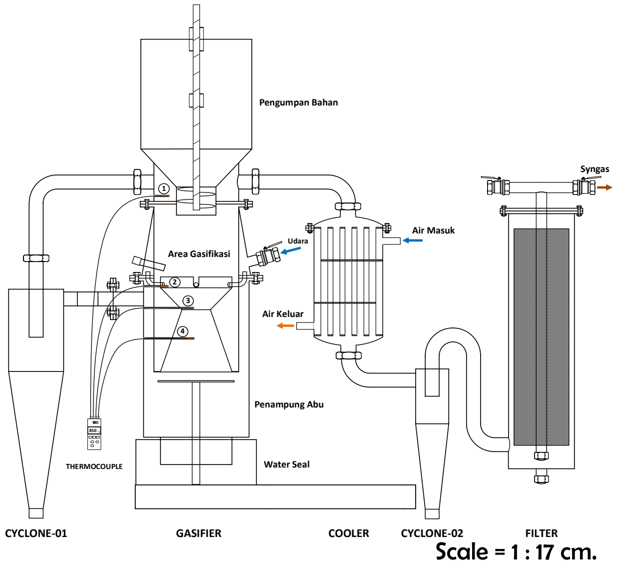

Figure 1. Biomassa Gasification Equipment

Framework

Existing processes within the framework of the research gasification can be explained in the following figure:

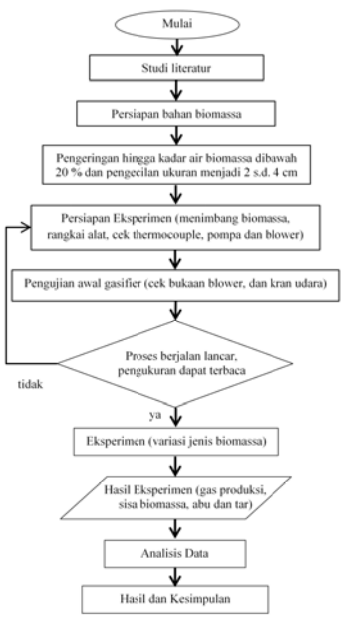

Figure 2. Research Flow Diagram

3. Results and Discussion

Results of Testing with Biomass Type Variable

1) Spesification of Raw Material

Spesification of raw materials are shown on Table 1.

Table 1. Spesification of raw material

No	Parameter	Spesifikasi tiap biomassa				
		Wood charcoal	Shell charcoal	Coconut shell	Woodchip	Rice husk
1.	Weight (kg)	8,44	13,78	13,78	5	4,85
2.	Size (cm)	2s.d.4	2 s.d. 4	2 s.d. 4	1 s.d. 2	± 1
3.	Moisture (%)	14	14	8,5	12,4	14,7
4.	Volatile matter (%)	11,64*	7,78*	70,77*	72,55*	53,24*
5.	Fixed Carbon (%)	76,25*	83,04*	18,31*	14,88*	14,01*
6.	Ash (%)	5,14*	1,92*	0,53*	1,54*	24,74*
7.	Calorific value (kcal/kg)	6.889*	7.392*	4.419*	4.198*	3.226*

*Source: *Munir, S., 2008*

2) Temperature profile of each biomass gasification

Gasification temperature profiles of each biomass are discussed below :

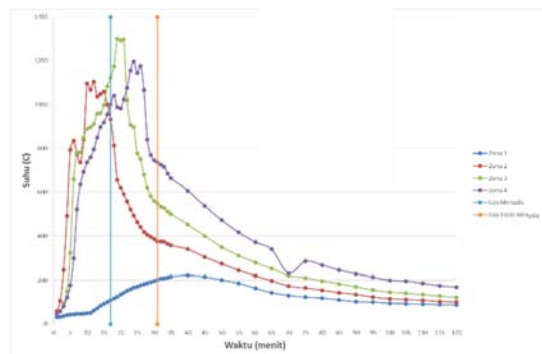

Figure 3. Gasification temperature profile of wood charcoal

From Figure 3. gas production could be seen burning in the 17th minute with temperature in zone 4 at 1002 ^{0}C, until the 31st minute with a temperature of zone 4 at 736 ^{0}C, where zone 4 is reduction zone of formation zone of CO and H_2 that operates on top temperature of 600 0C. From the temperature profile looks so rapid drop in temperature after the gas can not burn anymore that indicates a rapid rate of gasification, but the calorific value of charcoal as high as 6,889 kcal / kg so that the energy input and power output of the gasification of wood charcoal is also high.

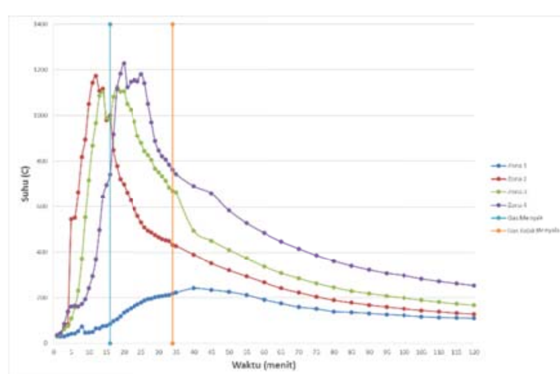

Figure 4. Gasification temperature profile of coconut shell charcoal

From Figure 4. gas production could be seen burning in the 16th minute with temperature in zone 4 at 741 ^{0}C, until the 34th minute with a temperature of zone 4 at 760 ^{0}C, where zone 4 is a reduction zone of formation zone of CO and H_2 that operates on top temperature of 600 ^{0}C. From the temperature profile looks so rapid drop in temperature after the gas can not burn anymore that indicates a rapid rate of gasification, but the calorific value of charcoal is high at 7,392 kcal / kg so that the energy input and power output of the gasification of coconut shell charcoal is also high.

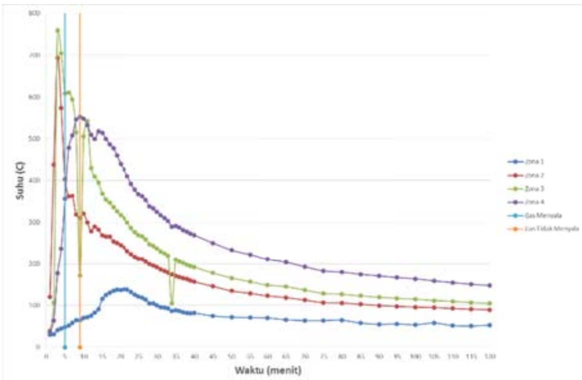

Figure 5. Gasification temperature profile of coconut shel

From Figure 5. gas production could be seen burning in the 5th minute with a temperature in zone 4 at 356 ^{0}C, until the 9th minute with a temperature in zone 4 at 553 ^{0}C. This condition occurs for original biomass, at the beginning of the process of gasification of biomass materials will release volatile substances are flammable so in less than 5 minutes and the temperature in zone 4 is still below 600 ^{0}C, the syngas can already burned. From the temperature profile looks so rapid drop in temperature after the gas can not burn anymore that indicates a rapid rate of gasification, but the calorific value of coconut shell as high as 4,419 kcal / kg to 13.78 kg mass, so that the energy input and power output of the gasification coconut shell is also high.

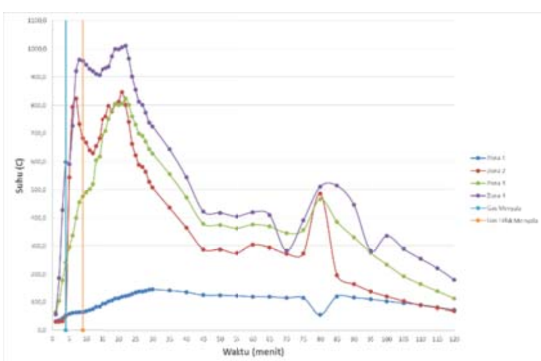

Figure 6. Gasification temperature profile of woodchip

From Figure 6. gas production could be seen burning in the 4th minute with a temperature in zone 4 at 599 ^{0}C, until the 9th minute with a temperature in zone 4 at 957 ^{0}C. At the beginning of the process of gasification of biomass materials will release volatile substances are flammable so in less than 5 minutes and the temperature in zone 4 is still below 600 ^{0}C, the syngas can be burned. From the temperature profile looks so rapid drop in temperature after the gas can not burn anymore that indicates a rapid rate of gasification, but the calorific value of woodchip is quite high at 4,198 kcal / kg with a mass of 5 kg, so that the energy input and power output of the gasification woodchip is low.

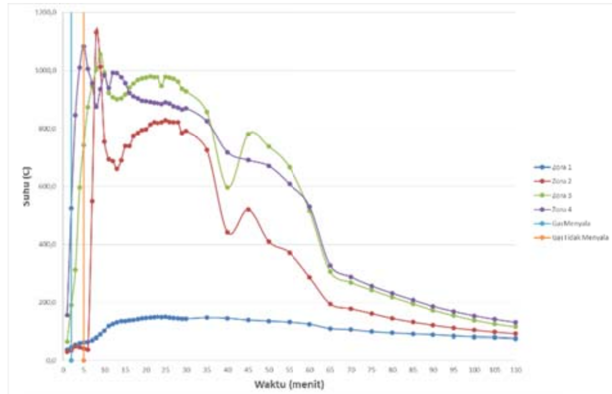

Figure 7. Gasification temperature profile of rice husk

From figure 7. Gas production could be seen burning in the 2nd minute with a temperature in zone 4 at 524 ^{0}C, until the 5th minute with a temperature in zone 4 at 1084 ^{0}C. This condition occurs for original biomass, at the beginning of the process of gasification of biomass materials will release volatile substances are flammable so in less than 5 minutes and the temperature in zone 4 is still below 600 ^{0}C, the syngas can already burned. From the temperature profile looks a rapid drop in temperature after the gas can not burn anymore that indicates a rapid rate of gasification, but the calorific value of rice husk is low at 3,226 kcal / kg with a mass of 4.85 kg, so that the energy input and output power of husks gasification low rice.

Results of variation testing of mixed coconut shell and shell charcoal

1) Weight of each mixture

Weight of each mixture of coconut shell and shell charcoal shown in table 2. below;

Table 2. Weight of each mixture

No.	Mixture	Weight	
		Shell	Shell charcoal
1.	Mixture A : 25% Shell and 75% Shell charcoal	2,025	5,740
2.	Mixture B : 50% Shell and 50% Shell charcoal	4,025	4,443
3.	Mixture C : 75% Shell and 25% Shell charcoal	6,140	2,080

Source: Weight data, 2014

2) Gasification temperature profile of mixed coconut shell and shell charcoal

Gasification temperature profile each mixture explained below :

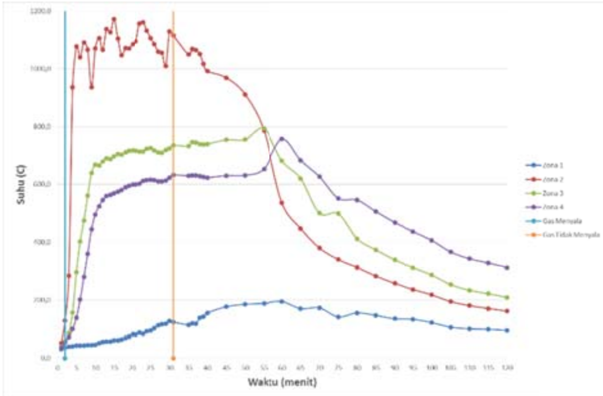

Figure 8. gasification temperature profile of mixture A

From Figure 8. gas production could be seen burning in the 2nd minute with a temperature in zone 4 at 53 ^{0}C, until the 31st minute with a temperature in zone 4 at 632 ^{0}C, zone 4 is a zone where the reduction zone or syngas formation which operates at temperatures above 600 ^{0}C. From the temperature profile looks fairly gentle drop in temperature after the gas can not burn anymore that indicates a low rate of gasification, but the calorific value of the biomass mixture is quite high at 6,617 kcal / kg with a mass of 7.765 kg, so that the energy input and the output power from the gasification of biomass mixture is also high.

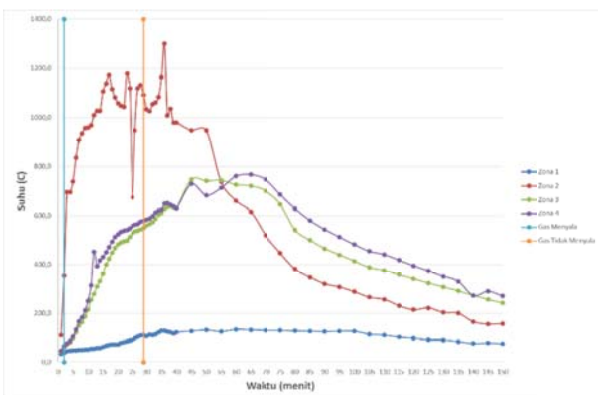

Figure 9. Gasification temperature profile of mixture B

From Figure 9. gas production could be seen burning in the 2nd minute with temperature in zone 4 at 65 ^{0}C, until the 28th minute with temperature in zone 4 at 574 ^{0}C, where zone 4 is a reduction zone of formation syngas CO and H^2 that operates in temperatures above 600 ^{0}C. From the temperature profile looks fairly gentle drop in temperature after the gas can not burn anymore that indicates a low rate of gasification, but the calorific value of the biomass mixture is quite high at 5,968 kcal / kg with a mass of 8.468 kg, so that the energy input and the output power from the gasification mixture B is also high.

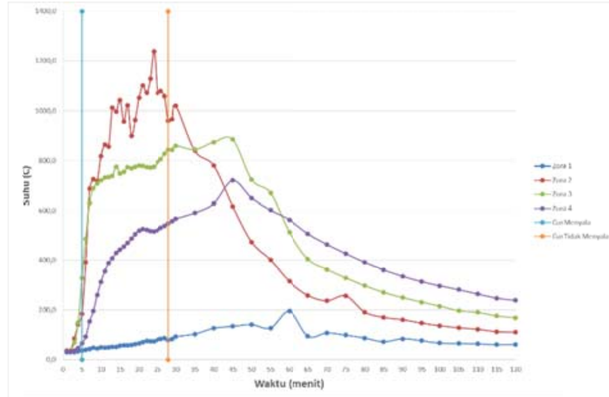

Figure 10. gasification temperature profile of mixture C

From Figure 10. gas production could be seen burning in the 5th minute with a temperature in zone 4 at 65 ^{0}C, until the 28th minute with a temperature in zone 4 at 546 ^{0}C, where zone 4 is a reduction zone of formation syngas CO and H^2 that operates on top temperature of 600 ^{0}C. from this process gasification, ash is also produced as much as 0,105 kg and 0.41 kg of residue. From the temperature profile looks fairly gentle drop in temperature after the gas can not burn anymore that indicates a low rate of gasification, but the calorific value of the biomass mixture is quite high at 5,171 kcal / kg with a mass of 8.220 kg, so that the energy input and the output power from the gasification of mixture B is also high.

The calculation of the rate of fuel consumption, specific gasification rate, the rate of gasification zone, the heat energy input and power output of the gasification

The calculation of the rate of fuel consumption, specific gasification rate, the rate of gasification zone, the heat energy input and power output of the gasification, shown in table 3. below:

Tabel 3. Biomass consumption rate (BCR), specific gasification rate (SGR), gasification zone rate (GZR), heat energy input (Q_f) and power output (Po) from biomass gasification.

No	Raw Material	Reactor		BCR (kg/h)	SGR (kg/m^2.h)	GZR (m/h)	Q_f (kcal)	Po (kW)
		Area (m^2)	Length (m)					
1.	Wood charcoal	0,2564	0,345	4,22	131,67	1,38	58.143	34,89
2.	Shell charcoal	0,2564	0,345	6,89	169,72	1,09	101.862	61,12
3.	Coconut shell	0,2564	0,345	6,89	644,93	4,14	60.894	36,54
4.	Woodchip	0,2564	0,345	2,50	195,01	3,45	20.990	12,59
5.	Rice husk	0,2564	0,345	2,43	283,74	5,18	15.646	9,39
6.	Mixture A	0,2564	0,345	3,88	60,57	0,69	51.378	30,83
7.	Mixture B	0,2564	0,345	4,23	73,39	0,77	50.533	30,32
8.	Mixture C	0,2564	0,345	4,11	80,15	0,86	42.508	25,50

From table 3. show, coconut shell biomass has the highest thermal energy input (Qf) and output power (Po) than the others because of the value of Qf and Po feedback related to the mass of biomass and calorific value of each biomass. The greater the mass of biomass and a calorific value of the biomass, Po and Qf value will be even greater. Conversely, if the mass and calorific value of the biomass is lower, then the value of Qf and Po will be lower as Po and Qf value of rice husk biomass.

4. Conclusion

Based on the results of the research and discussion, the following conclusions from the study of the characteristics of various types of biomass gasification process in a downdraft gasifier are:

1) Temperature profiles of various biomass gasification shows the syngas already appeared in the early minutes (in the 2nd minute until the 5th) gasification or at temperatures up to 34^{0}C - 350^{0}C as the coconut shell gasification, woodchip, rice husk. Time of gas-fired depends on the mass of the biomass and the length of the formation of charcoal.
2) Optimal results from various types of biomass gasification showed that coconut shell charcoal easily produce fuel gas for 2,825% of the weight of the biomass and gases can be burned for 19 minutes and resulted in 1,92% of ash and 29,57% of charcoal. Mixture of 25% shell and 75% coconut shell charcoal easily produce fuel gas for 5,013% of the weight of the biomass and gases can be burned for 30 minutes and resulted in 1,61% of ash and 5,1% of charcoal.

Solid waste all around us are many kinds and not only biomass, hopefully this research continues with another kind of solid materials such as solid waste gasification from household so that could be an option to process solid waste into energy.

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