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Renewable Energy from Biomass - A Potential Contribution and Energy Analysis

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Abstract. Biomass is considered the renewable energy source with the highest potential to contribute to rapid increasing of industrialization and motorization because of widespread availability, abundant, relatively cheap. This paper is aims to show availability of biomass energy in a way of utilizing the energy for power generation. Energy can be extracted from biomass through gasification process. A set up of suction biomass gasifier and operated under stable condition which fueled from wood waste and air as gasifying agent. The biomass feeding rate was varied from 3 to 5.5kg/hr. Result show that producer gas contains CO in 20-30% in volume and H_2 found to be varying between 14 and16% vol. The low heating value (LHV) from this woody gasification around 4 -5 MJ/Nm^3. The main objective of the present study is to investigate the use biomass energy and its contribution to energy mixing.

Key words: Bio-energy; Biomass; Gasification

INTRODUCTION

Biomass is seen as important source for energy security and tackling climate change due to low cost by-product in agriculture and forestry, low ash and sulfur contents (Paulo, D., 2004). The growing demand in energy consumption and less dependency on fossil fuels have drive biomass to become one of security energy source. Malaysia is blessed with huge capacity of fossil fuel resources such as oil, gas, and coal as well as biomass, solar and hydropower. From the past decades, Malaysia showed significant growth in economic activities and electricity demand (energy use per unit GDP) about 1.5 times based on several decades (Sumiani Yusoff, 2006).

In Malaysia, power generation is fueled mostly by fossil-based: natural gas and oil. The fuel mix was encouraging Malaysia to move inline with Malaysian Fifth Fuel Strategy to include 5% energy supply from renewable energy (Lee Chung Lau, 2009). Therefore, energy source is targeted from oil palm residues and other agricultural industries such wood, sugar cane and paddy. In spite of being one of the largest palm oil producer in the world, 19 million tones of crop residues per year can be produced in the form of empty fruit bunch, fiber (Rahman, A.M., T.L. Keat, 2006). Table 1 shows the reneawable energy resources in Malaysia towards the goal of technology commercialization (Chua, S.C., 2011).

Table 1: Recent renewable energy potential in Malaysia.

Renewable energy	Residue	Electrical potential (MW)
Oil palm	Empty fruit bunches	570
	Fibres	1080
	Shells	550
	Palm Oil Mill Effluent	330
Paddy	Rice husk	72
	Paddy straw	83.9
Sugar	Bagasse	0
Wood	Sawn timber	50.1
	Plywood & veneer	3.6
	Moulding	2.2

Source: Malaysia Energy Centre, Comprehensive Biomass Study 2005

In view of technology commercialization, there is big opportunities to be utilizing the energy to cater supply demand as in Fig. 1. Ensuring sufficient continuous supply of biomass seems to be the biggest challenge in Malaysia. Although it was reported by several studies, commercialization of research findings has not been fully undertaken on a large scale. Until now, Malaysian government has targeted renewable energy for power generation and as transport fuel (Peck, Y.G., L. Zhi Dong, 2008). With the aim of maximizing solid yield, gasification is seen versatile process to convert original solid biomass into gaseous energy. Gasification is a

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thermo chemical conversion process with limited supply of air as gasifying agent. The gas is called producer gas with heating value of 4-5MJ/m^3 (Giltrap, D.L., 2003; Yamazaki, T., 2005) are able for applications such as in reciprocating engines, as fuel in furnace, boiler, and gas turbine.

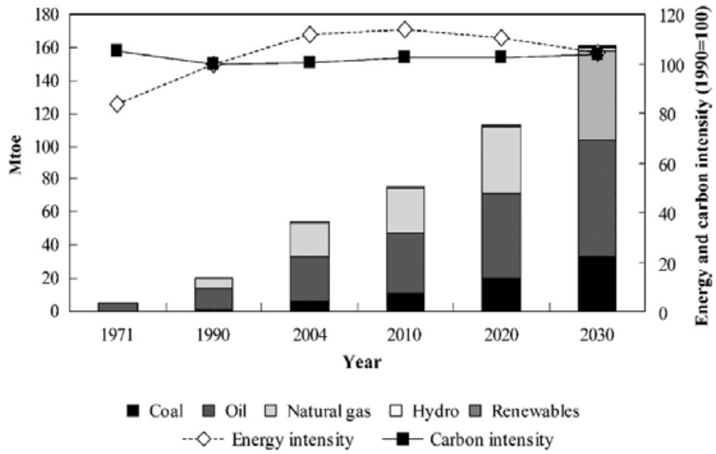

Fig. 1: Energy demand in Malaysia (Peck, Y.G., L. Zhi Dong, 2008).

Fixed bed gasifiers have been widely used in the energy conversion due to their cheapest method and can produce the producer gas with less tar content (Pathak, B.S., 2008). In gasification lignocellulosic residue is heated above 650°C to produce producer gas (CO, CH_4, H_2). The availability of biomass to generate fuel and energy boost the importance of gasification plant to be established in Malaysia. Current research aims to address related issues regarding gasification performance and energy analysis. Result obtained is shown clearly for further energy exploitation.

2. Methods:

2.1 Feedstock and Characterization:

Biomass feedstock from wood chip material is obtained from furniture factory at Nibong Tebal, with rubber wood as the main component was used for this study. The fresh wood chip with high moisture was open-air dried for a day. The non- granular- shaped wood chip in range of 20 mm in both length and width consisting of 37.6% of the sample was fed up into the gasifier by batch. The thickness approximately 3 mm with calculated bulk density 609.8 kg/m^3 which is almost suitable for commercial application. The characteristic of wood chip sample was first investigated in TGA analyzer (Perkin Elmer TGA7) in order to identify percentage of fixed carbon, volatile matter and ash. A 12 mg of biomass was used in this experiment. Meanwhile, LHV was measured using Bomb calorimeter (Yoshida Seisakusho 1013B). The results obtained are presented in Table 2. EFB (Empty fruit bunch) is compared due to palm oil by-product; seem to have in average composition of wood chip and it will not be used in this work. At higher concentration of sulfur in rice husk can cause sulphation phenomenon and lead corrosion in the gasifier or boiler.

Table 2: Proximate analysis of biomass feedstock.

Proximate analysis (wt.%)	Wood chip	[a]Rice husk	[b]EFB
Moisture	14.9	11.2	7.8
Fixed Carbon	11.36	18.4	8.36
Volatiles	78.12	81.6	79.34
Ash	0.22	23.5	4.5
Ultimate analysis (wt.%)			
Carbon	43.9	38.9	43.5
Hydrogen	4.94	5.1	5.7
Nitrogen	0.09	0.6	1.2
Oxygen (by diff.)	51.07	55.4	48.9
Density (kg/m3)	609.8	617	-
HHV (MJ/kg)	18.5	15.29	15.22

[*]present study, [a]Kirubakaran (2009), [b]Pooya (2011)

2.2 Experimental Setup:

This reactor was batch fed downdraft gasifier having constant diameter. A type of suction biomass gasifier is used with parameter of 1.11 m tall and 46 cm in diameter with made of mild steel. Biomass fuel is fed through the top opening, steel grate in 42 cm diameter at the bottom is generally considered as a support for the biomass fuel.

The cone refractory structured is throated as to provide smooth gravitational movement of the biomass fuel. The air is drawn through a 55mm gap at the top of the gasifier while lower cylinder contained the ash zone. The 520 L/min ring blower was fitted after the exit port of the gasifier to induce producer gas from the gasifier. A frequency inverter was used to control the blower speed. An orifice meter was installed after the suction blower to measure the producer gas flow rate.

The gasification behavior of wood chips was first investigated at suction blower frequencies varied from 15 Hz to 50Hz with an increment of 5Hz. Flow rates for every increment were recorded with a U-tube manometer. Later, producer gas sample was collected in sampling bags, and then injected into a gas chromatograph (Agilent module 4890 GC) with thermal conductivity detector (TDC) to sense the substance. Char from producer gas is trap at cyclone separator. Meanwhile, condensate condensed at pre-cooler and condenser, also cause a temperature down to ambient. The carbon conversion efficiency presents the amount of carbon in the biomass material converted into gases shown in equation below. Where m_{char} is the amount of char remaining in the ash bin and $m_{biomass}$ is the amount of biomass used in the experiment. The carbon percentage (%C) in wood was measured separately from ultimate analysis. The carbon conversion efficiency for each run was calculated as follows;

$$\text{Carbon conversion efficiency} = \left[1 - \frac{m_{char}}{m_{biomass}\, x\%C}\right] x100\% \quad (1)$$

RESULTS AND DISCUSSION

The average flow rate of producer gas is shown in Fig. 2. Correlation between the actual and fitted linear line is acceptable, obtained determination coefficient value of 0.942. To guide the selection of gasification conditions, suction blower frequency is limit to the 35 and 40 Hz due to stability flare observed at flare stack (see Fig. 3) compared to other frequency. Stable and high temperature flare is significant output of the gasification process. Biomass feed rate is associated with suction blower frequency. Due to non – granular shaped, biomass feed rate seem inconsistence and might attribute bridging. Other studies shows particle size and shape of biomass affect gasification rate, to turn volatile matter into gas (Yamashita, T., 2006). ER of the experiment was calculated (see Table 3) varying between 0.26-0.32. For fixed bed gasifier, (Zainal, Z.A., 2002) calculated the ER for gasification to be about 0.2-0.43.

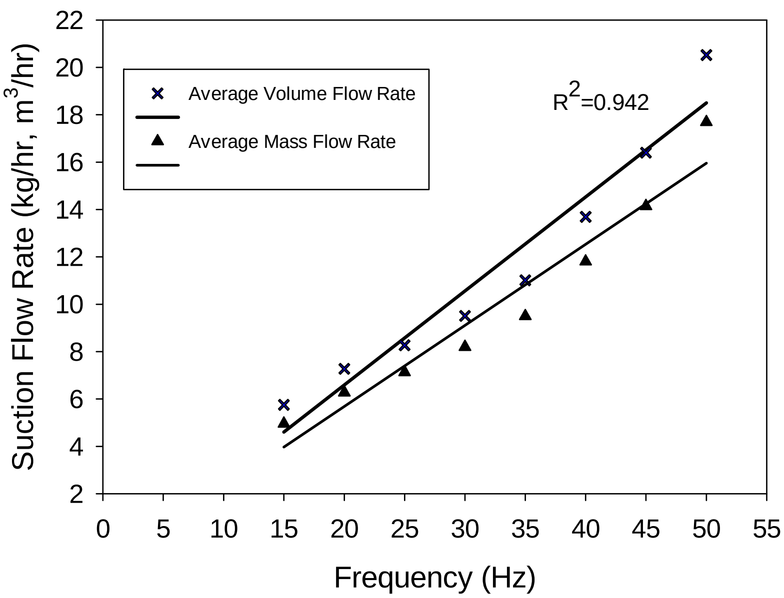

Fig. 2: Blower suction flow rate.

Table 3: Biomass gasification experimental run details.

Blower Frequency (Hz)	Average Producer Gas Flow Rate (kg/hr)	Air Flow Rate (kg/hr)	Biomass Feed Rate (kg/hr)	Equivalence Ratio (ER)	Cold Gas Efficiency (%)
35	11	6.27	3.4	0.291	76.6
35	11	6.27	3.1	0.319	84
35	11	6.27	3.7	0.268	70.4
40	13.7	7.8	4.3	0.289	75.4
40	13.7	7.8	4.8	0.259	67.5
40	13.7	7.8	4.1	0.304	79.1

3.1 Zone Temperature:

Figure 3 mentioned temperatures in the gasification zone are linked to the suction blower frequency. The average gasification temperatures are ranging from 700- 725°C and 750-775°C respective to 35 and 40 Hz. Meanwhile, average exit temperatures were 240-250°C and 260-270°C respectively. Similar result also reported [6]. The significant of bed temperature is associated with feeding rate with the rapid of decomposition of hemicelluloses fractions. Table 1.1 also mentioned the performance of the gasifier system. Cold gas efficiency is found to be an average of 75.5% with a maximum of 84%. Cold gas efficiency is the fraction of power output of producer to the power input from biomass, so the higher value could explain better biomass conversion into gas.

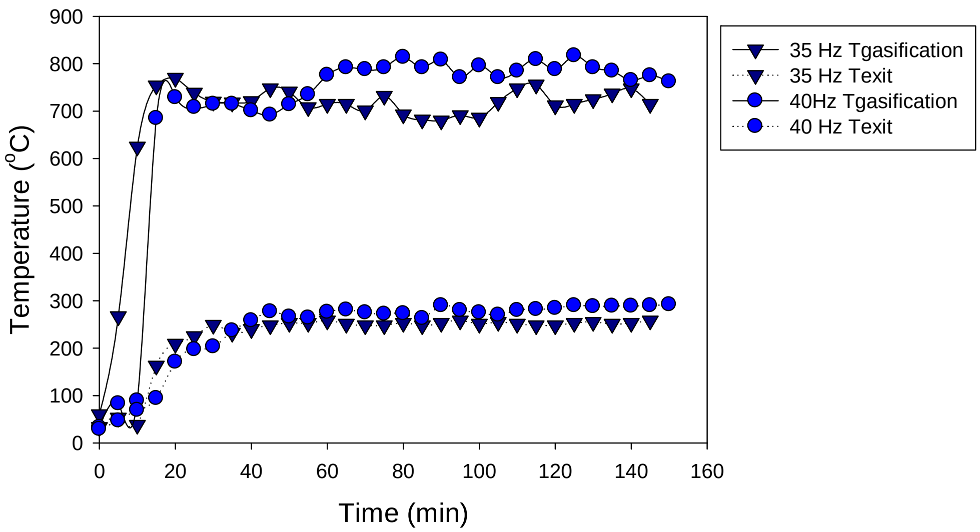

Fig. 3: Suction Gasifier Temperature Profile at 35, and 40 Hz.

From the observation, 35 and 40 Hz have the most stable flare with less smoke. Flare is reddish which indicates good combustion of the producer gas compared to other frequencies. At 30 Hz, more smoke was observed due to lower gasification temperature (580-630°C).

(a) Flare Temp: 580-630°C	**(b)** Flare Temp: 680-720°C	**(c)** Flare Temp: 740- 780°C

Fig. 3: Snapshot Flare of Burning of Producer Gas with Different Motor Frequency (a) 30Hz (b) 35Hz (c) 40Hz

3.2 GC Analysis:

The result of GC analysis was presented in Table 4 at operating frequency of 35 and 40Hz respectively. When the gasification temperature was in average of 700- 725°C, LHV of gas was 4.24 MJ/m^3. With a small increase of ER to 0.31, the LHV of gas reaches maximum value of 5.44 MJ/m^3 with cold gas efficiency 79.1% respectively. Carbon monoxide and methane was the main component that responsible for the increment of LHV of producer gas. With the increase of ER, probably methane and carbon monoxide component also increased. Other researchers observed the trends of both components decrease start at ER 0.388 and LHV of gas is acceptable for use further in CI engine or power generation (Paulo, D., 2004; Zainal, Z.A., 2002; Hasler, P., 1999).

Table 4: Gas composition.

Blower frequency (Hz)	35	35	40	40
Average gasification temperature (°C)	725	725	775	775
Equivalence ratio	0.27	0.29	0.29	0.31
H_2 (% by vol. by diff.)	10.4	10.54	10.5	11.27
O_2 (% by vol.)	5.67	6.02	11.63	5.63
N_2 (% by vol.)	48.5	47.6	39.2	39.2
CO (% by vol.)	18.98	19.84	22.5	25.57
CH_4 (% by vol.)	1.84	2.13	2.08	2.64
CO_2 (% by vol.)	14.61	13.87	14.09	15.69
Sum	100	100	100	100
LHV (MJ/m^3)	4.24	4.50	4.77	5.44

3.3 Carbon Conversion Efficiency:

Table 1.3 shows the biomass-gas conversion which in average of 89.6%. It explained percentage of reacted biomass in the gasification process. Size and shape of biomass feedstock would affect volatile release rate inclusive with gasification temperature. Higher reaction rates could optimize the char as it converts into CO. When ER was at 0.31, the biomass-gas conversion achieve as high 92.6 %. As ER decrease, carbon conversion also decreases due to lack of oxygen to enhance gasification process. The average efficiency is compares well with (Cao, Y., 2006), obtained 87-98 % for fixed bed gasifier.

Table 1.3: Amount of char collected.

Frequency (Hz)	35	35	40	40	Average
Equivalence ratio	0.27	0.29	0.29	0.31	-
m_{char} (kg)	0.18	0.13	0.24	0.12	0.17
$m_{biomass}$ (kg)	3.4	3.1	4.3	3.7	3.63
η_{carbon} (%)	87.9	90.4	87.3	92.6	89.6

3.4 Energy Analysis and Mass Balance:

Energy analysis was performed on the system. Fig. 4 illutrated the energy ouptut at each stage of the of the system accordance to producer gas flow rate, product name, and heating value of the producer gas. The total ouput energy is 11.8 kW which is 31.5% lower than energy input. Energy loss is due to heat loss in the transporting pipes which were not insulated. Char is one byproduct which have LCV of 23.69 MJ/kg (Mook Tzeng Lim, 2008). The char collected was 0.12 kg/hr, so carbon conversion efficiency,η_{carbon} was found to be 61.4%. Mass balance of 98.9% is shown in Table 5. This compares well with (Murat Dogru, 2002) with mass balance of 95%. Mass loss could probably from tar which was deposited in the pipes. However, if moisture in wood chips increases, the mass balance dramatically increases and, hence encountered difficulties in maintaining the producer gas quality.

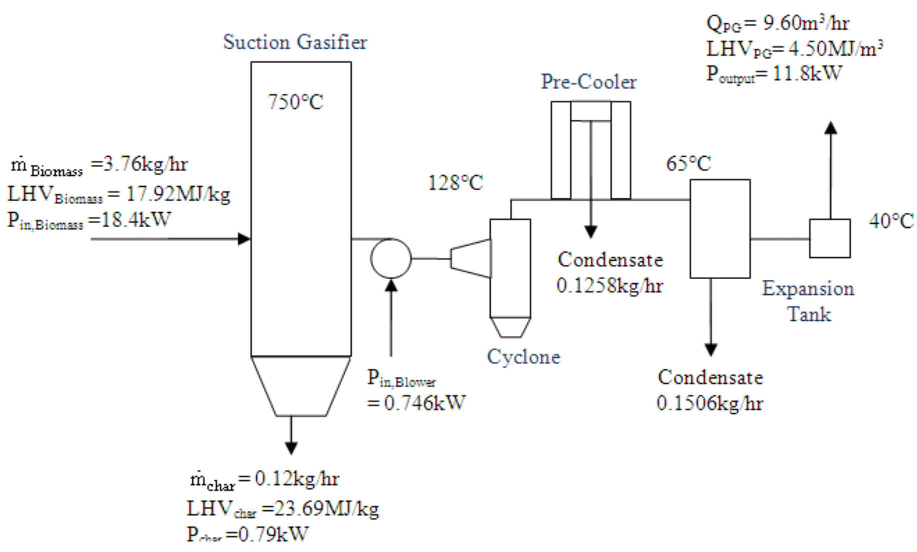

Fig. 4.6: Schematic Diagram of Suction Gasifier Energy Analysis.

Table 5: Mass balance at 35Hz with the gas flow rate about 140Lpm.

MASS INPUT	Weight (kg/hr)	MASS OUTPUT	Weight (kg/hr)
Wood	3.7	Producer gas	9.4
Mass of air	6.2	Condensate	0.27
		Char	0.12
Total	9.9	Total	9.79

4. Conclusion:

This paper has shown that biomass energy is effective in order to enhance mixing energy in Malaysia. Gasification is one of the method which can be imitated and implement to reduce the dependency to the fossil fuels. Wood chip gasification was excellent in producing higher thermal energy. This is due to fuel characteristics, low in ash content and higher in heating value comparable to rice husk feedstock. All stable experiment of suction biomass gasifier has established under various operating conditions. The optimum value of ER is 0.31 at cold gas efficiency of 79.1%. Non- granular size and shape of biomass could explain percentage of reacted biomass which turn into gas and leaved as char. The average carbon conversion efficiency is found to be 89.6 %.

Overall performance in terms of consistence production of good quality gas is satisfactory with optimum conditions could lead LHV as high 5.44 MJ/m^3. So, LHV is suitable to be used in CI engine and electrical power generation. This demonstrates the biomass would give a positive impact for bio-energy production plant.

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