Asian Journal of Applied Sciences (ISSN: 2321 – 0893)
Volume 05 – Issue 03, June 2017

Effect of Air-vapor Flow Rate on Syngas Production Compositions of Updraft Horse Manure Gasification

Rudy Sutanto[1, *], Pandri Pandiatmi[2], Ida Bagus Alit[3], and Mirmanto[3]

[1] Mechanical Engineering Department, Mataram University
Jl. Majapahit no. 62 Mataram, NTB, 83125, Indonesia

[2] Mechanical Engineering Department, Mataram University
Jl. Majapahit no. 62 Mataram, NTB, 83125, Indonesia

[3] Mechanical Engineering Department, Mataram University
Jl. Majapahit no. 62 Mataram, NTB, 83125, Indonesia

[4] Mechanical Engineering Department, Mataram University
Jl. Majapahit no. 62 Mataram, NTB, 83125, Indonesia

[*] *Corresponding author's email: r_sutanto10 [AT] yahoo.com*

ABSTRACT— ***Utilizing biomass as an alternative energy source is needed. This is due to fossil fuels that begin to thin out in line with technological developments. Biomass can be converted into syngas using gasification processes with a device called gasifier. Experiments producing syngas from horse manure were conducted using an updraft gasifier. The aim of this study is to know the effect of air flow rate mixed with vapour on the syngas composition. The air flow rates used were ranging from 10 l/min to 30 l/min. The results show that the gas resulted in the experiment is CO, H_2, and CH_4, and the best quality of syngas happened at air flow rate of 30 l/min and vapor flow of 0.024 l/min with CH_4 0.18%, H_2 37.34%, CO 6.93%.***

Keywords— Updraft gasification, biomass, horse manure, air-vapor

---

1. INTRODUCTION

Gasification is the process of converting carbon compounds to convert liquids and solids into gas fuels (CO, H_2, CO_2, CH_4 and H_2O) by combustion processes with limited air supply between 20% - 40% stoichiometry air composition [1]. During the gasification process, the process area will be formed according to the temperature distribution at the gasifier reactor. These areas are dries, pyrolysis, reduction, and burning. Each region occurs in the temperature range between 25°C to 150°C, 150°C to 600°C, 600°C to 900°C, and 800°C to 1400°C, Peter [1]. The gas produced from this gasification process is called a gas producer or syngas.

Gasification that we know is gasification with coal feed and agricultural waste, anonymous [2], but gasification with raw material of livestock waste especially horse manure biomass has never been done. In fact, horse manure biomass has great potential to be developed as a gasification raw material because of its fine grain size and contains high levels of carbohydrates, fats, and crude fiber. The contents increase the production of carbon which will indirectly increase the production of methane and carbon monoxide, Sihotang [3]. Therefore, gasification of horse manure needs to be developed. However, despite having good potential, there are also weaknesses. Horse manure biomass has high moisture content and if used directly it will be difficult to process and can disrupt gasification performance. As a consequent, an initial processing of horse manure biomass needs to be performed. The initial treatment is to reduce the moisture content in horse manure biomass (impurities) through the drying process.

Effect of air flow rate on the syngas production has also been studied by Vidian [4]. He investigated a coconut garment gasification process with air flow rates of 70.2 l/min, 91.4 l/min and 122.4 l/min. The experimental results indicated that increasing the air flow rate elevated the temperature in the reactor, gas composition, gas flow rate, gasification efficiency and combustion temperature. Nevertheless, to increase the gas production of gasification significantly, the incoming air flow can be mixed with vapor, Sepe et al. [5], Chaudhari et al. [6]. In [5], high temperature vapor and high temperature air-vapor gasification have been investigated. Those two models were performed using solar energy on the top of the gasifier. They found that using those two methods resulted in high quality syngas (nearly 42% H_2 and 35% CO). Compared with conventional methods, these improved the process efficiency from 65% to 81% and the H_2 increased from 30% to 55%. In [6], vapor gasification was studied using vapor flow rates ranging from

1.25 to 10 g/h/g of char and at temperatures of 700°C, 750°C, and 800°C. They found that the production of the gasification was mainly a mixture of H_2, CO, CO_2, and CH_4 with a high H_2/CO molar ratio at the highest temperature and vapor mass flow rate. They concluded that to increase the H_2 production, simple vapor gasification could be utilized. Furthermore, Pocioni et al. [7] studied vapor gasification. They stated that H_2 and CO were influenced by both temperature and vapor pressure and the conversion range of H_2 and CO was 50-80%.

Due to the above paragraphs, this study investigates the effect of air flow rates mixed with water vapour on the syngas production of horse manure gasification processes. The horse manure is used in this research because of its contents. As explained by Sihotang [3], the horse manure has fine grain sizes and comprises carbohydrate, fat and crude fibers that can increase the production of methane gas and carbon monoxide gas. Furthermore, Sihotang [3] stated that production of horse manures was approximately of 5.5 ton/ year/ horse. This exhibits that the horse manure has high potential energy that can be converted into syngas productions.

2. EXPERIMENTAL SET UP

The schematic diagram of the test facility is shown in Fig. 1. It consists of an updraft gasifier, a boiler, air flow meter, a blower, ash stirrer and a scrubber. Air flowed from the ambient using a blower trough the flowmeter where the air flow rate was measured. From the flowmeter, the air entered the boiler. The boiler containing clean water was heated up at approximately of 80°C so that view amount of vapour generated and flowed with the air. The air and vapour flowed to the updraft gasifier. In the gasifier, the air and vapour react with gas and finally formed syngas. The temperature in the gasifier was maintained at approximately 900°C and the temperature was measured using a K-type thermocouple read using a digital thermocouple reader. The dimension of the gasifier can be seen in Fig. 1 with the unit in mm. The gasifier was insulated using rice husk to minimize the heat lost to the ambient.

The air mass flow rates employed were 10 l/min, 15 l/min, 20 l/min, 25 l/min and 30 l/min. The flow rate was measured using a flowmeter model vertical floated ball with a resolution of 0.1 l/min. Meanwhile, the vapor flow rate used were 0.008 l/min, 0.013 l/min, 0.017 l/min, 0.021 l/min and 0.024 l/min respectively. The vapor flow rate was measured using a sight level glass. Furthermore, the syngas composition was determined using a gas chromatography model GC7900 developed by Techcomp. To measure CO and H_2 gas, the temperature of the gas should be set up at approximately 150°C with a current of 60 mA, while to measure CH_4 and CO_2, the gas temperature should be at 200°C and a current of 60 mA.

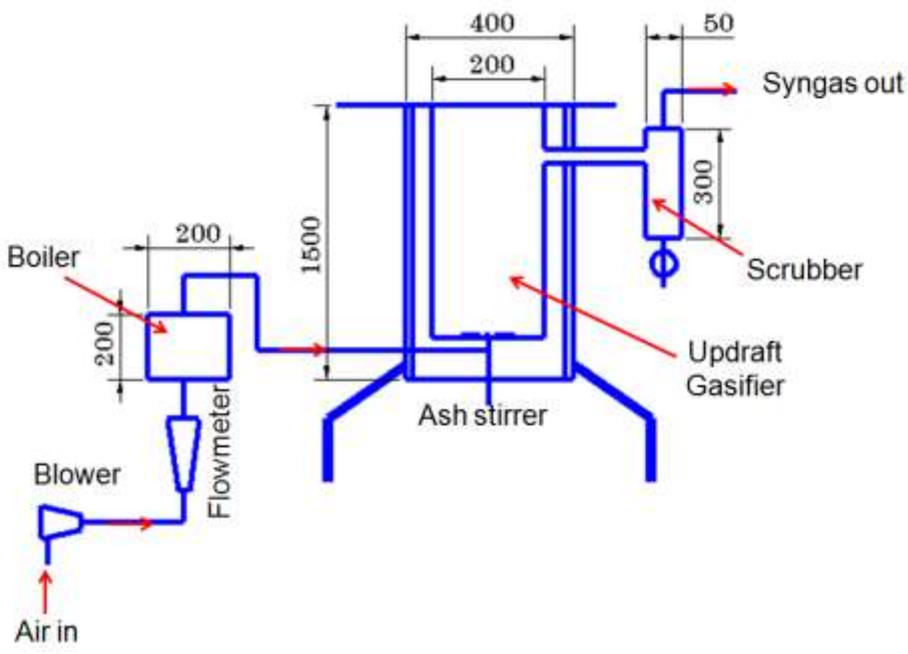

Figure 1: Schematic Diagram of the Test Facility (No Scaling and Unit in mm)

Horse manure biomass has a high moisture content of approximately 75% in wet basis and if it is used directly it will be difficult to process and can disrupt gasification performance. Initial processing of horse manure biomass needs to be done. The initial treatment is the reduction of moisture content in horse manure through the drying process first. The drying process is carried out in direct sunlight for 3 days until the moisture content is obtained about 10%.

Furthermore, 5 kg of horse manure biomass is inserted into the reactor manually from the top of the reactor. The boiler is filled with 4 liters of water and then heated to 80 ° C with 4000 watts heater and then air is washed through the bottom of the boiler with variations of 10, 15, 20, 25 and 30 l/min respectively. Once everything is ready, the operation of the gasification reactor is done by burning the biomass through the reactor using a match. After the flame burns, the air is flowed with varying flow rates. After syngas out of the top hole of the reactor, the syngas is passed scrubber then put into a plastic bag. Furthermore, the syngas composition was tested using GC7900 chromatography with TCD detector to measure CO, CO_2, CH_4, H_2 levels in percentage volume.

3. RESULTS AND DISCUSSION

The results of biomass test of horse manure can produce flammable gas as shown in Table 1. For CO gas, increasing the air-vapor flow rate decreases the CO volume percentage. This is because the air flow rate used will increase the amount of oxygen in stoichiometry air boundaries for the gasification process. Therefore, high air flow rate will decrease CO content. The CO production obtained in this study is presented in figure 2. A similar result was found by Pacioni et al. [7]. They stated that increasing the air flow rate decreased the CO gas, but increased the H_2 gas. When the rate of air flow entering the boiler increases, the rate of air flow - water vapor increases, see Table 1. This will cause air - moisture into the gasifier reactor is excessive. As a result, the %volume of H_2, CO_2, and CH_4 increases, however, the CO gas decreases as shown in table 1. This finding was also found by Chaudhari et al. [6].

Table 1: GC-TCD analysis results of gas products for variations of the agent gas flow rate

Agent gas flow rate (l/min)	Compound Name	R.Time (minute)	Height (mm)	Area (mm²)	% Volume	Type
10 l/min (air flow rate)	Methane	0.753	775	3041	0.0629	XB
0.008 l/min (vapor flow rate)	CO_2	1.731	4932	56060	1.1447	BB
	CO	0.101	2322	21912	11.0447	BB
	Hydrogen	0.429	2645	9131	4.6026	BV
15 l/min (air flow rate)	Methane	0.751	844	3248	0.0663	XB
0.01 l/min (vapor flow rate)	CO_2	1.736	6881	78066	1.6149	BB
	CO	0.106	2335	21719	10.2260	BB
	Hydrogen	0.554	30264	24992	11.7670	BV
20 l/min (air flow rate)	Methane	0.780	1102	5332	0.1085	VB
0.014 l/min (vapor flow rate)	CO_2	1.731	11685	133641	2.7205	BB
	CO	0.106	2335	21719	10.2260	BB
	Hydrogen	0.441	16977	64865	25.2102	BV
25 l/min (air flow rate)	Methane	0.788	1658	8838	0.1788	VB
0.021 l/min (vapor flow rate)	CO_2	1.730	12533	143780	2.9082	BB
	CO	0.115	2428	21801	8.1959	BB
	Hydrogen	0.441	18960	73238	27.5333	BV
30 l/min (air flow rate)	Methane	0.788	1658	8838	0.1788	VB
0.034 l/min (vapor flow rate)	CO_2	1.730	12533	143780	2.9082	BB
	CO	0.115	2240	21283	6.9273	BB
	Hydrogen	0.443	29163	114713	37.3382	BV

As seen in Table 1, increasing the air flow rate of 10 l/min and vapor flow rate of 0.008 l/min results in an increased Methane and Hydrogen, however, increasing the air and vapor flow rates from 25 to 30 l/min and from 0.021 to 0.034 l/min does not affect the % volume of Methane, but still affects the % volume of Hydrogen. This may indicate that the maximum increased flow rates of air and vapor for Methane have been achieved. Nevertheless, the main goal of conducting gasification is to produce H_2 gas, so that this research needs to be extended to apply more air and vapor flow rates.

The results of tests that have been performed show that during the gasification process, the chemical reaction that occurs is an endothermic reaction. This reaction requires heat from the outside during the process. However, the temperatures occurring in the gasification reactor are higher along with the higher air-vapor flow rate to the gasifier. It is also found by Sihotang [3]. Sihotang [3] stated that the increase in air flow rate increased the temperature in the reactor, gas composition, gas flow rate, gasification efficiency and fire fuel temperature. The high temperature of approximately 900^{o}C will result in biomass burning processes of horse manure in the gasifier become more perfect. Therefore, more CO_2 is produced, see figure 3. If the heat generated in the oxidation process is higher, then this heat will affect the pyrolysis process. The higher the reactor temperature, the better the pyrolysis process and form a larger carbon. However, the process of reducing CO_2 and carbon gas occurs because it breaks down into carbon monoxide gas.

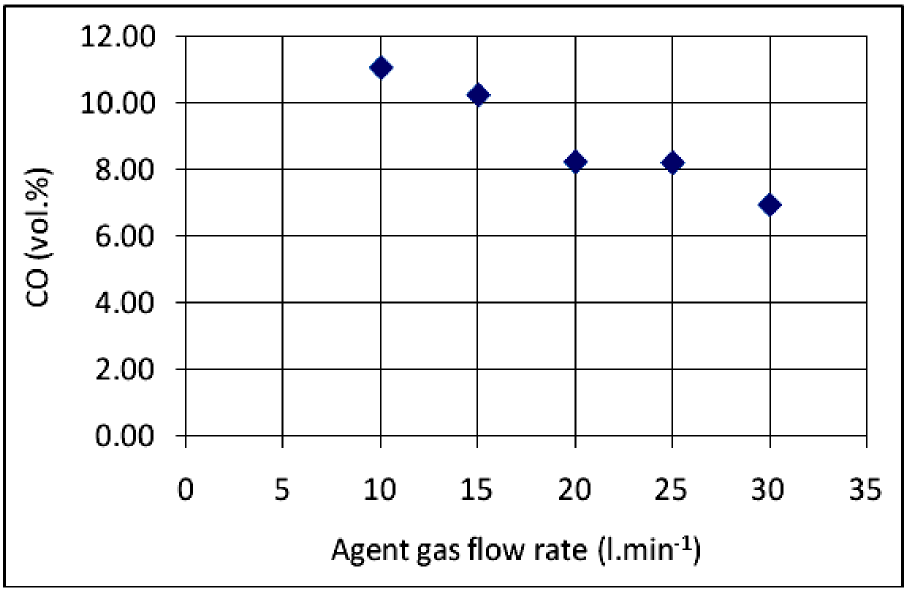

Figure 2: Effect of Agent Gas (Air-Vapour) Flow Rate on CO Production

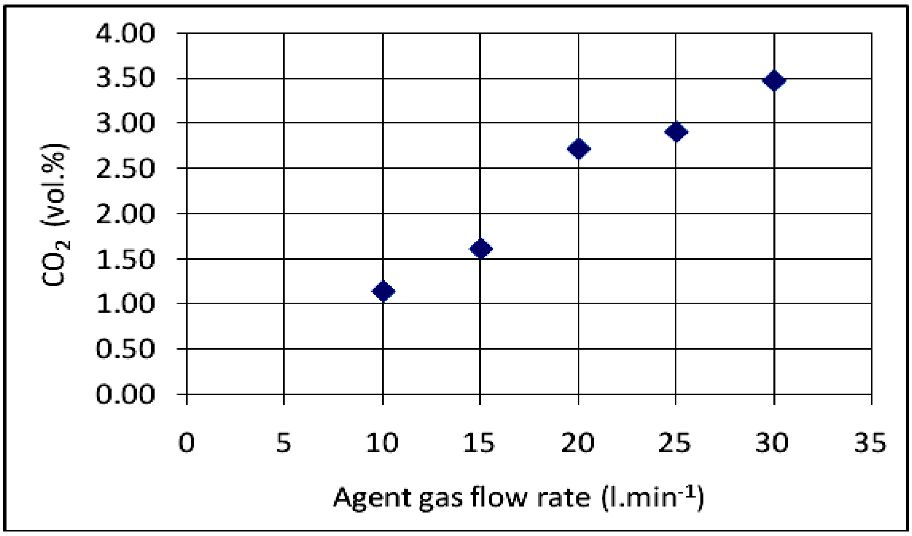

Figure 3: Effect of agent gas (air-vapour) flow rate on CO_2 Production

Furthermore, methanation process is the reaction of methane gas formation where H_2 gas will react with carbon and form CH_4 gas. The high H_2 gas formed in the reaction process of carbon monoxide reduction by the vapor, see figure 5, increases with the increase in air-vapour flow rate. The CH_4 gas formed will increase with the increase of agent gas (air-vapour) flow rate with an average of 33.7% increase, see Figure 4. While Chaudhari [6] showed the similarity that with the greater air / vapour flow rate the resulting H_2 gas increases.

High temperatures resulted in a reaction process of carbon monoxide reduction by vapour results in increased hydrogen, see figure 5. High temperatures lead to easier combustion, therefore, this process produces CO_2 gas levels in syngas will be greater. Since most of the CO gas produced in the process of oxidation has become CO_2 gas, only a small proportion of CO gas is contained in syngas and decreased by an average of 10.7%, see figure 2. This result is in accordance with the results of the study by Pacioni et al. [7]. They said that high air velocity produced a decrease in CO gas content.

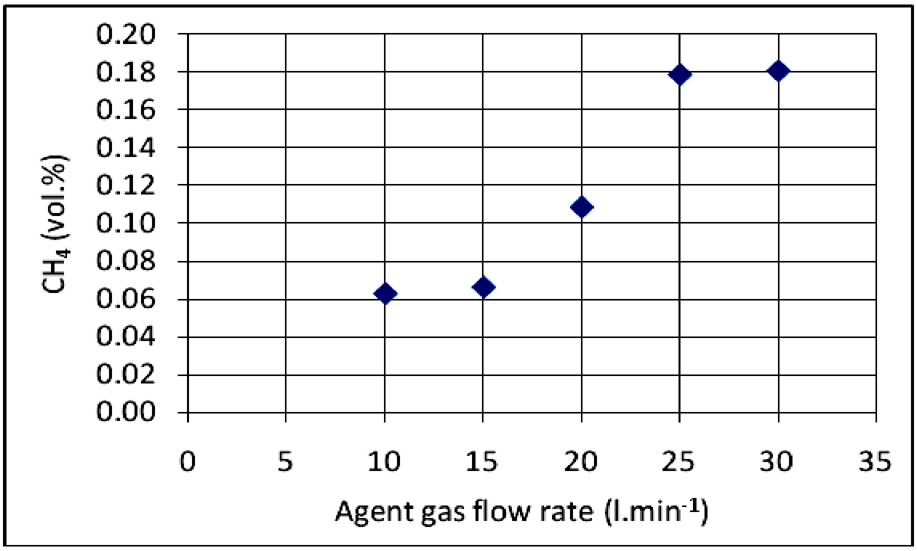

Figure 4: Effect of Agent Gas (Air-Vapour) Flow Rate on CH_4 Production

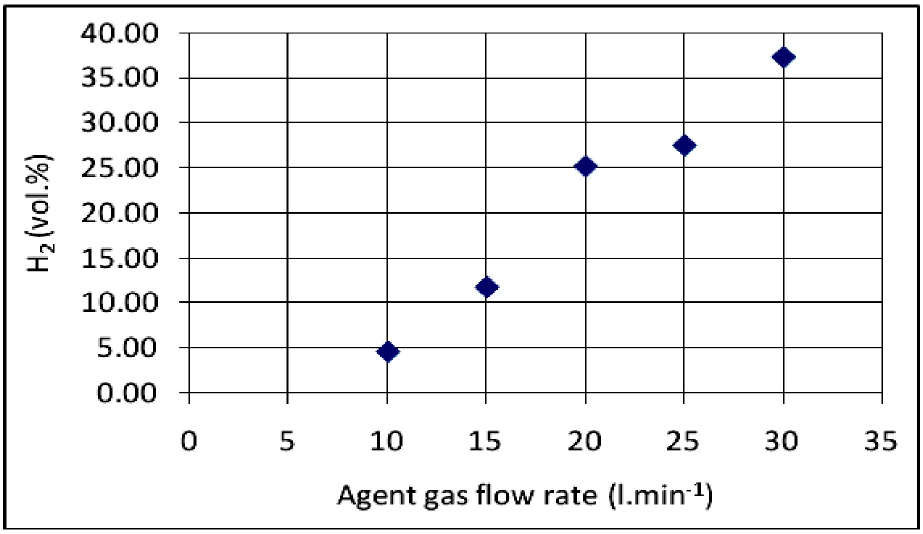

Figure 5: Effect of Agent Gas (Air-Vapour) Flow Rate on H_2 Production

4. CONCLUSION

From the result of gasification research of horse manure biomass on updraft type gasifier reactor with variation of air-vapour flow rate can be concluded that:

1. Increasing the air-vapour flow rate raises the H_2 and CH_4 but decreases the CO.
2. The best condition is at the gas flow rate of 30 l/min with CH_4 0.18%, CO 6.93% , H_2 37.34%.

5. ACKNOWLEDGEMENT

The authors would like to acknowledge the Mechanical Engineering Department, Mataram University for the facility and everyone who has helped in conducting the experiments and writing the paper.

6. REFERENCES

[1] L. Peter. “Advanced System in Biomass Gasification – Commercial Reality and Outlook”, Paper, the III International Slovak Biomass Forum, Bratislava, February 3-5, 2003.
[2] Anonymous, Pusat Data dan Informasi Pertamian, Departemen Pertanian Republik Indonesia, http://deptan.go.id.

[3] B. Sihotang, " Kandungan Senyawa Kimia Pada Pupuk Kandang Berdasarkan Jenis Binatangnya", Avaliable at r.yuwie.com/blog/ entry. Accession date: 29 November 2010.
[4] F. Vidian, "Gasifikasi Tempurung Kelapa Menggunakan Updraft Gasifier Pada Beberapa Variasi Laju Alir Udara Pembakaran", Jurnal Teknik Mesin, vol. 10, pp. 88-93, 2008.
[5] A.M. Sepe, J. Li, M.C. Paul, "Assessing Biomass Vapor Gasification Technologies Using A Multi-Purpose Model", Energy Coversion and Management, vol. 129, pp. 216–226, 2016.
[6] S.T. Chaudhari , A.K. Dalai, N.N. Bakhshi, "Production of Vapour and/or Syngas (H_2 + CO) via Vapor Gasification of Biomass-Derived Chars", Energy Fuels, vol. 17, no. 4, pp. 1062–1067, 2003.
[7] T.R. Pacioni, D. Soares, M. Di Domenico, M.F. Rosa, R.P.M. Moreira, H.J. José, Bio-syngas production from agro-industrial biomass residues by vapor gasification, Waste Management, vol. 58, pp. 221–229, 2016.