The Improvement of Carburater Efficiency Using Biogas-based Venturi

Ni Ketut Lasmi[a], Alamta Singarimbun and Last Wahyu Srigutomo

[1]*Physics of Earth and Complex System, Fac. of Mathematics and Natural Sciences, Institut Teknologi Bandung, Jl. Ganesa 10 Bandung, Indonesia 40132*

Abstract. The elimination of the fossil fuel subsidy by the Indonesian government has caused an increase in fuel prices, and a solution to find a relatively cheap and environmentally friendly alternative energy is needed. Biogas is one of the sources of renewable energy that has a potential to be developed, especially in farming area where the abundant animal excrement is not yet optimally used and causes environmental problems. Addressing this issue, we have developed an innovation by making a biogas and air mixer instrument through venturi pipe, using the basic theory of fluid mechanism in order to increase the use of biogas as an electricity source. Usually, biogas-based electric generators use dual fuel system such as fossil fuel and biogas to perform combustion due to the low octane contained in the biogas. By replacing the readily available manufactured venturi with the modified venturi, optimal combustion can be reached with using only single fuel of biogas. The results of the experiments show that the biogas debit on carburetor increases from 13 to 439 watts consuming biogas fuel from 0.22 to 4.96 liter/minute, respectively. The amount of combusted biogas depends on the value of the load power. Within the scope of our results, the maximum voltage reached is about 211.13 – 211.76 volts which is feasible to use for 220 volts electrical appliances

1 Introducton

In the last couple of years, the use of renewable energy has been increasing in Indonesia. If it is well organized and properly used, it can be a supplement for the limited fossil energy. One of the renewable energy sources that can be used is biogas [1] which can be transformed into bioelectric. Bioelectric is an electricity that is obtained from biogas resulted by cow excrement, liquid and solid waste through anaerobic digestion [2]. The composition of biogas varies depending on the source of the biogas, for example cow excrement [3]. Biogas is one of the energy technology solutions to overcome society's problem of electricity. This technology can be immediately applied to society in order to fulfil the national energy need.

The use of purified biogas as machine fuel will decrease greenhouse gas emission and provide other natural benefits, because combustion of biogas releases smaller amount of nitrogen oxide, hydrocarbon and carbon monoxide compared to the combustion of benzene and diesel oil. Compared to natural gases, biogas combustion releases smaller amount of hydrocarbon, carbon monoxide and carbon dioxide, but bigger amount of nitrogen oxide [4]. Another benefit is that a machine that uses

[a] Corresponding author : k.lasmi@yahoo.com

biogas fuel sounds softer than machine with diesel oil. Biogas conversion is done by changing the fuel in generator that uses mixture of benzene and biogas by single fuel biogas generator. Because the octane of biogas if very low, the available commercial venturi is modified by a new venturi having different sizes. The purpose of making this instrument is to increase the efficiency of biogas as an environmentally friendly electricity source [5, 6], and affordable by all citizen in Indonesia.

2. Materials and Methods

2.1 Research location and design of biogas mixer instrument

This research is conducted at Pondok Pesantren Baituraahman, Bojong Dusun village, Cikoneng Ciparai sub-district, Bandung, which is the location of biogas digester. This research is carried out through several steps: mixing the biogas and air in the modified venturi, measurement of CH4 emission by the self-made sensor after the biogas passing through 2 kW generator as shown in Fig.1 [8]. To produce the biogas, we utilize six biogas reactors which are airless installation enabling the cow excrement to be decomposed optimally thus decreasing the methane emission.

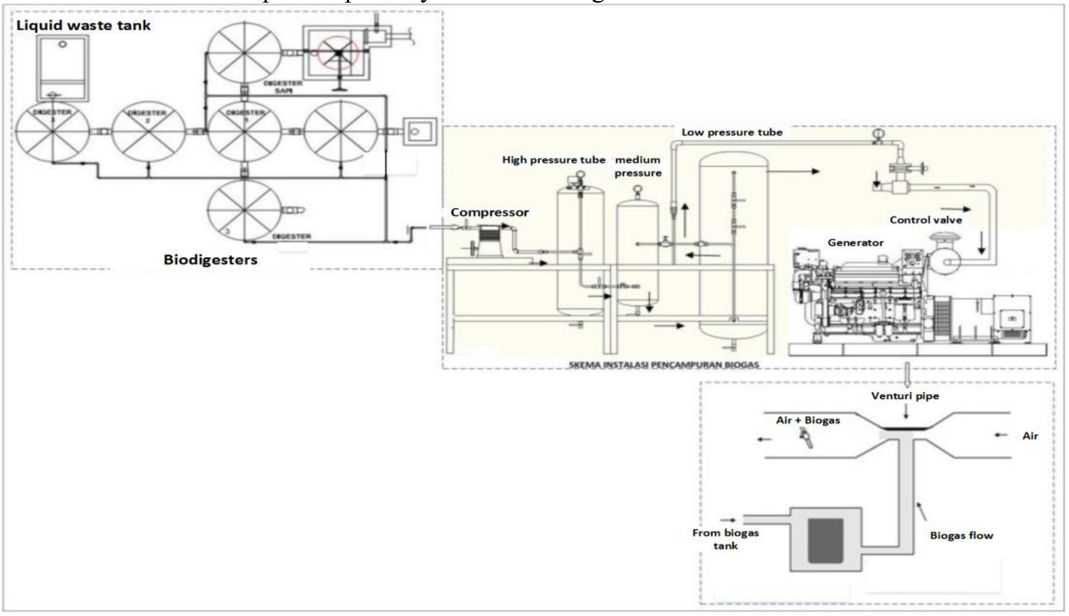

Figure 1. Scheme of biogas mixer instrument

2.2 Generator modification

Modification on the generator was done to increase the biogas generator performance. There are two modified components: carburetor and the venturi. The function of carburetor is to mix air and biogas with a certain ratio in the combustion room. The modification of carburater is done by replacing the original factory manufactured venturi made from lathed copper rod having 6 mm inlet and 3 mm outlet diameters by the modified brass venturi having 5.0 mm inlet and 3.5 mm outlet diameters and 150.0 mm long (Fig. 2 and Fig. 3). The venturi is then attached to the carburetor and serves as the air-biogas mixer.

Figure 2. Modified carburater.

Figure 3. (Up) original factory manufactured venturi, (Down) modified venturi

2.3 Formulation of output power using venture

Fluid velocity in a tube can be measured by Bernoulli's and continuity equations under assumptions that the fluid follows ideal fluid basic equations [9]. To calculate the pressure difference of biogas- air mixture at the inlet and outlet of the venturi, the continuity equation is used [10, 11, 12] yielding

$$Q_{ideal} = A_1 v_1 = A_2 v_2 \tag{1}$$

In its general form Bernoulli's equation can be expressed as [13, 14],

$$\frac{p}{\rho} + \frac{v^2}{2} + gz = \text{constant} \tag{2}$$

whereas for two different diamaters the equation can be written as [15]

$$\frac{p_1}{\rho} + \frac{v_1^2}{2} + gz_1 = \frac{p_2}{\rho} + \frac{v_2^2}{2} + gz_2 \tag{3}$$

If the flow is horizontal ($z_1 = z_2$), then

$$\frac{p_1}{\rho} + \frac{v_1^2}{2} = \frac{p_2}{\rho} + \frac{v_2^2}{2} \tag{4}$$

with p1: pressure at point 2 (Pa), p_2: pressure at point 2 (Pa), v_1: velocity at point 1 (m/s), v_2: velocity at point 2 (m/s), and: ρ:density (kg/m^3).

The non-horizontal effect in the flow can be easily incorporated by inserting height difference (z_1–z_2) into the equation. The combination of continuity equation (1) and Bernoulli's equation (4) results the theoretic flow velocity equation if $A_2 < A_1$:

$$Q = A_2 \sqrt{\frac{2(p_1 - p_2)}{\rho\left[1 - \left(\frac{A_2}{A_1}\right)^2\right]}} \tag{5}$$

where Q: flow velocity (m3/s), A_1: area of part 1 (m^2), A_2: area of part 2 (m^2), and p_1–p_2 = p: pressure difference (Pa). The flow velocity can be written as

$$Q = c_v Q_{ideal} = c_v A_T \sqrt{\frac{2(p_1 - p_2)}{\rho(1-\beta^4)}} \tag{6}$$

where $A_T = (\pi d^2)/4$ is the area of venturi neck (m^2), c_v: discharge venturi coefficient, and β = d/D: neck diameter ratio.

The result of theoretic flow velocity will be higher than the flow velocity in real measurement because of the difference of "real world" with assumptions that are used in Bernoulli equation. The difference can approximately be from 1 – 40% [14]. If the diameters of both pipes are known, the fluid flow velocity in venturi pipe can be measured by flow meter as well as the pressure.

Experimentally, the measurement of generator performance is expressed as

$$Q_{measured} = \frac{Q_1 + Q_2 + ... + Q_n}{n} \quad \text{(liter/minute)} \tag{7}$$

The actual heat of biogas depends on CH4. Heat is very vital to determine the machine capability. To measure heat, the standard thermodynamics formula can be used

$$H_{u,actual} = \frac{V_{CH_4}}{V_{tot}} \rho_{CH_4,actual} H_{u,normal} \quad (\text{kJ/m}^3) \tag{8}$$

with

$$\rho_{CH_4,actual} = \rho_{CH_4,\text{standard}} \frac{P_{actual}}{P_{\text{standard}}} \frac{T_{actual}}{T_{\text{standard}}}, \quad (\text{kg/m}^3) \tag{9}$$

CH4,standard = standard methane density (=0.72 kg/m^3)
Pactual,standard = total pressure and standard pressure of biogas, (mbar)
Tactual,standard = standard temperature (273 K) and actual temperature from the biogas fuel
The flow velocity of biogas can be measured with the equation:

$$Q = vA = \frac{m}{Vol} \quad (\text{kg/m}^3), \tag{10}$$

where ρ: density (kg/m3), m: mass (kg), and Vol: volume (m^3), v: gas flow velocity (m/s), dan A: cross section (m^2). The flow velocity [13] is written as:

$$Q = \frac{m}{t} \quad (\text{kg/h}), \tag{11}$$

The biogas consumption is calculated by the equation:

$$E = QH_{u,normal} \quad (\text{kJ/kg}), \tag{12}$$

The output power can be measured as:

$$P = VI \quad (\text{watt}), \tag{13}$$

where V: output voltage (volt) and I: current (ampere).

3. Results and Discussion

The result is based on the experimental data obtained by direct observation in location. The data are taken by using different loads. The biogas combustion quality spreading out from the venturi exhibited straight splash pattern which is different from the original manufactured venturi, resulting a stable output current.

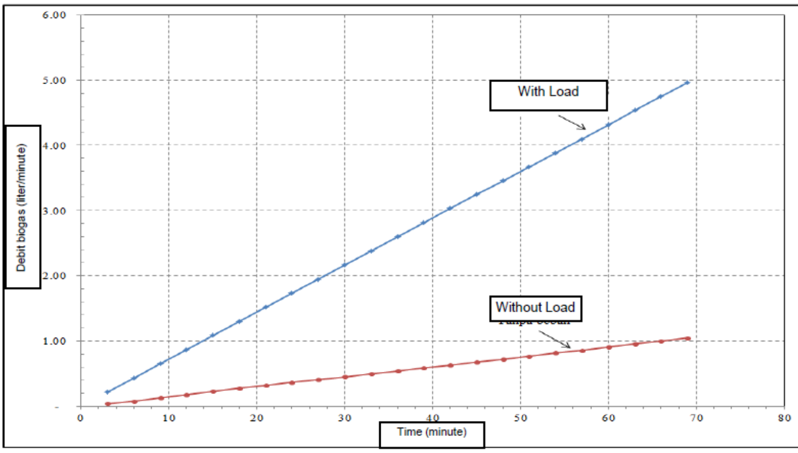

Figure 4. Graphics of biogas debit vs. time (with and without load)

The plot between biogas debit vs. time (with and without load) is depicted in Figure 4. This figure shows that there is a significant relation between biogas debit and time that is changing linearly. The longer the time, the higher the biogas debit is and vice versa. This indicates that the modified venturi provides efficient injection of biogas resulting perfect combustion.

Plot of the relation between the output power and the biogas debit is shown by Fig. 5 indicating the liniear relation between the load power and biogas debit. The plot between the actual power with biogas debit is also shown in the same figure indicating the improvement in combustion efficiency as the result of venturi modification. The power generated by the generator increases with time inline with the icrease in biogas consumption. The actual power outputted varies from minimum 21.12 watts up to 658.73 watts with biogas fuel consumption from 0.22 liter/minute to 4.96 liter/minute. The differences between the load power and the measured power are approximately 33.36% - 38.43%. The application of modified venturi affects the generated power, energy, fuel consumption, heat, fuel mass and generator efficiency. The more biogas fuel is combusted, the more output power that is obtained. The electric voltage obtained by the generator reached value of 220 volts when applied without load and reached approximately 211.13 V – 211.76 volts when load is applied which is still a stable voltage range.

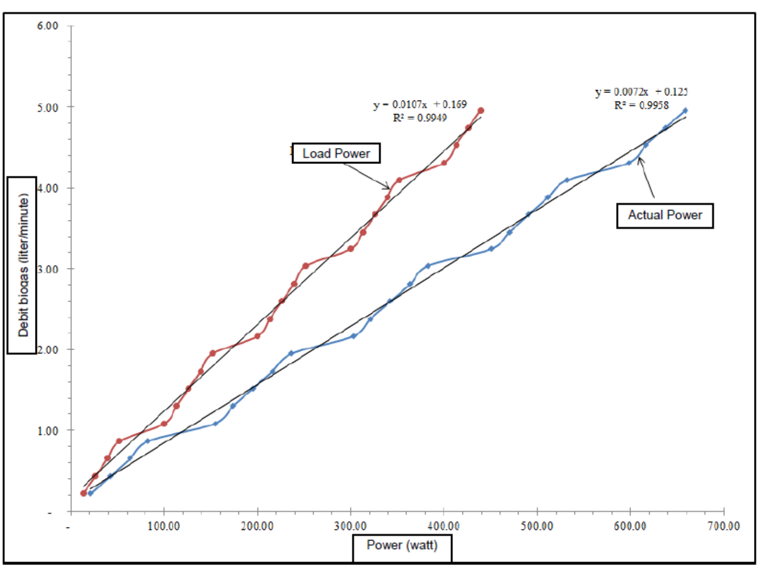

Figure 5. Graphic of relation between fuel debit with output power

4. Conclusion

The result shows that the increase in biogas debit is linearly related to the increase in output power. The actual power outputted varies from minimum 21.12 watts up to 658.73 watts with biogas fuel consumption from 0.22 liter/minute to 4.96 liter/minute. The electric voltage obtained by the generator reached value of 220 volts when applied without load and reached approximately 211.13 V – 211.76 volts when load is applied which is still a stable voltage range.

Acknowledgements

A sincere thank to Pondok Pesantren Baituraahman and the farmers in Cikoneng Kecamatan Ciparai Kabupaten Bandung and Lembaga Ilmu Pengetahun Indonesia (LIPI) Bandung for their help and support during the data collecting.

References

1. Herberg,T.C., Enskat,M.and Abmann, D., Conference Issue Paper. Renewables 2004 – International Conference for Renewable Energies, Bonn, Germany, 2014
2. Gunnerson, C.G. and Stuckey,D.C.,Anaerobic Digestion: Principles and Practises for Biogas System. The World Bank Washington, D.C. USA, 1986
3. Deublein,D. and Steinhauser,A., Biogas from Waste and Renewable Resources, Wiley-VCH Verlag Gmbh and Co. KgaA, Germany, 2008
4. Vijay, V.K., Chandra, R., Subbarao, P.M.V. and Kapdi, S.S., Biogas Purification and Bottling into CNG Cylinders: Producing Bio-CNG from Biomass for Rural Automotive Applications, The 2nd Joint International Conference on “Sustainable Energy and Environment 2006”, Bangkok, 2006
5. Porpatham, E., Ramesh,A. and Nagalingam, B.,Investigation on the effect of concentration of methane in biogas when used as a fuel for a spark ignition engine. Internal Combustion Engines Laboratory, Department of Mechanical Engineering, Indian Institute of Technology Madras, Chennai – 600 036, India, 2007
6. Prastya, R., Susilo,B. and Lutfi, M., Pengaruh Penggunaan Bahan Bakar Biogas terhadap Emisi Gas Buang Mesin Generator Set. Jurnal Keteknikan Pertanian Tropis dan Biosistem. Vol. 1 No. 2, Juni 2013, pp. 77-84
7. Lasmi, N.K., Singarimbun, A., Souisa, M., Rajagukguk, J. and Amunidin, A.,Desain Instrumen Pencampur Biogas dan Udara Untuk Menghasilkan Daya Listrik, Proceeding Seminar Nasional Energi Indonesia (Senendo), Universitas Atma Jaya, Yogjakarta, 2013, pp.111–114
8. Lasmi, N.K., Singarimbun, A. and Srigutomo, W., Pengukuran Perbedaan Tekanan dan Laju Aliran Biogas Pada Pipa Venturi Menggunakan Generator Berbahan Bakar Biogas Untuk Menghasilkan Energi Listrik, Prosiding Simposium Nasional Inovasi dan Pembelajaran Sains 2015 (SNIPS 2015), 8 dan 9 Juni 2015, Bandung Indonesia, 2015,pp. 29–32
9. Serway and Faugh, CBS Collega Physics, College Publishing, 1985, pp. 45-46
10. Munson, B.R., Young, D.F., and Okiishi, Th.H., Fundamentals of Fluid Mechanics, fourth edition. John Wiley and Sons, Inc. USA, 2002
11. White, F.M.,Fluid Mechanics, Second Edition. McGraw-Hill, Ltd, 1986
12. Abbas, H.A., Hasan, M. and Lucas, G.P., Experimental and theoretical study of the gas-water two phase flow through a conductance multiphase Venturi meter in vertical annular (wet gas) flow. University of Huddersfield Repository, Nuclear Engineering and Design. 241 (2011) 1998-2005
13. Zucker, R.D. and Biblarz, O., Fundamentals of Gas Dynamics, second edition, Published by John Wiley and Sons, Inc., Hobeken, New Jersey, 2002,26,41, pp. 64-66
14. Munson, Bruce R., Young, Donald, F., Okiishi, andTheodore, H., Mekanika Fluida, Jilid I, Edisi Keempat, Jakarta: Erlangga, 2004