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The Effect of Packed Column Addition to the Performance of Biogas Stove

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Abstract

Concomitant depletion of energy sources and fuel shortages that occurred in Indonesia today, it takes a cheap alternative energy sources and environmentally friendly, one of which is biogas. Biogas can be produced from organic wastes such as garbage, food scraps, manure and food-industry wastes. The fermentations of the above materials to produce biogas largest component levels are CH_4 (55% - 75%) and CO_2 (25%-45%). Utilization of biogas as a fuel is still in the household and unused optimally. This is due to biogas CO_2 still contains high levels of heat generated so that efficiency is still low. To reduce the amount of CO_2 contained in the biogas is to absorb CO_2 using K_2CO_3 solution continuously in a reactor (absorber). Through this research, we can know the difference between the performance of biogas stoves are using absorption and without absorption using a burner that has a fire pit which varies the burner flame holes with a diameter of 2 mm to produce power of 0.47 kW and an efficiency of 61.64% without absorption and0.65 kW and efficient by 71.74% with absorption. The burner with 3 mm diameter of fire pits produce power of 0.50 kW and an efficiency of 59.44% without absorption. However, 0.56 kW power and 82.09% of efficiency with absorption. Next, a fire pit burner with a diameter of 4 mm produce power of 0, 55 kW and an efficiency of 54.81% without absorption. Whereas 0.65 kW power and 73.99% efficiency with absorption.

Keywords

Absorption, Biogas, CH_4, Packed Column, K_2CO_3

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1. Introduction

Human dependence upon fossil fuels caused the reserves of these energy sources are gradually reduced, in addition to the impact on the environment, such as air pollution. In situations like this, the search, development, and deployment of new alternative energy technologies that are cheap, environmentally friendly and renewable (renewable) energy such as solar, wind energy, water energy and other alternative energy sources become important. Especially when there is an increase in fuel prices will have an impact on the poor who are most affected by this price increase. Alternative energy sources have been found as a substitute for fuel, one of which is Biogas. Research on biogas was generally conducted by previous researchers, among others: [1], [2], [3], [4], [5], [6], [7], [8], [9], and [10].

Several methods of purifying biogas i.e. physical absorption, chemical absorption, the absorption of the surface of a solid, cryogenic methods, methods of chemical conversion and separation by membrane. Each method has advantages and disadvantages in terms of economic processes, raw materials, technology and operation. It takes an easy, simple and easy

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on the raw material that can be for a biogas purification process.

Efforts to purify biogas from CO_2 gases have been carried out using absorbent K_2CO_3 in a packed column.

Next [11] conducted a research by comparing the rate of absorption and balance, vapor- liquid CO_2 in solution K_2CO_3 hot, with DEA and DEA solution with stericaly hindered amines.

Another research is research by CO_2 removal where absorbennya K_2CO_3 in a packed column and the stripper such as a tray columns which is carried out by [12].

Next is the study by [13] studying the process of stripping CO_2 from a solution of K_2CO_3 / $KHCO_3$ with a piperazine catalyst using a speed -based approach.

Then [14] conducted a simulation of the CO_2 recovery using the absorption column and sripping along with CO_2 purification unit for a gas-turbine exhaust gases.

Later [15] upgrading the quality of biogas by removing CO_2 and H_2S using a packed column reactor. The liquid solution used is sodium hydroxide (NaOH), calcium hydroxide ($Ca(OH)_2$) and mono-ethanolamine (MEA). Liquid solvent circulated through the column, direct contact with biogas flows through the opposite (counter flow). This technique proved to promise to upgrade the quality of biogas.

This study specifically learns about the effect of adding a packed column and without a packed column with absorbent K_2CO_3 to the performance of biogas stove where this research has not been done by previous researchers.

1.1. Definition of Biogas

Biogas is a gas produced from the decomposition of organic matter, carried out in anaerobic (closed on free air) to produce a gas which is mostly methane (which has flammable properties) and carbon dioxide. The gas formed is called swamp gas or biogas. A good temperature, for fermentation is 30°-55°C. At this temperature, microorganisms can work optimally, remodel organic ingredients. In general, biogas is a mixture of 50-70% methane [CH_4], 30-40% of carbon dioxide [CO_2], 5-10% hydrogen gas [H_2] and the rest of other gases.

Table 1. Biogas composition and amount in a bio-gas unit.

Type of gas	Content (%)
Methane	60 – 70
Carbon dioxide	30 – 40
Nitrogen	3
Hydrogen	1 –10
Oxygen	3
Hydrogen sulfide	5

Source: [1].

Judging from the huge potential of biogas then do the assessment and making installation as well want to know the extent to which alternative energy biogas by using absorbent can be developed by way of the test this fuel on a biogas stove.

1.2. Stage of Mixing / Absorption

Because the solvents used are K_2CO_3 then absorption will occur chemically because of chemical reactions directly between CO_2 with a solution of K_2CO_3. The process of absorption or the separation of CO_2 by K_2CO_3 can be seen in the following reaction:

$$CO_2(aq) + K_2CO_3(aq) + H_2O \rightarrow 2KHCO_3(aq)$$

Absorption above is a chemical reaction that occurs, due to the occurrence of a chemical reaction directly between CO_2 with a solution of K_2CO_3. But in the liquid phase, in addition there is a thin layer of liquid also contained the reaction zone. The chemical reaction that occurs is irreversible, where the CO_2 in the gas phase will be absor bed by the liquid phase K_2CO_3 solution.

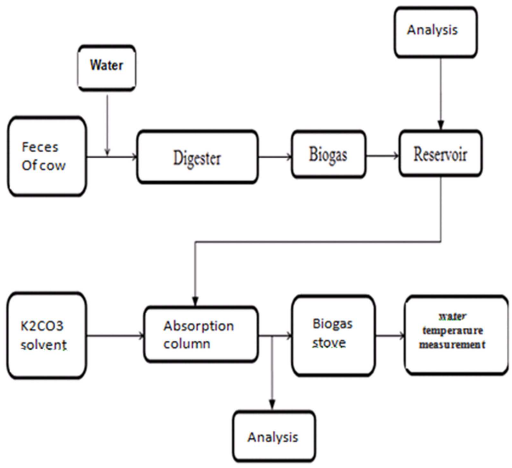

Figure 1. Research scheme.

1.3. Working Principle of Packed Column

a. Absorption column is a column in which, there are different substances phase flow in opposite directions which can cause chemical components transferred from one liquid phase to another phase occurring almost every chemical reactor. This process can be either gas absorption, distillation, dissolution occurs in all chemical reactions.

b. The gas mixture which is the output of the reactor is fed down absorber tower. In the absorber, there will be contact between the two phases namely the gas phase and liquid phase resulting in diffusional mass transfer in a feed gas from the bottom of the tower.

2. Method

2.1. Location and Time Research

Making the installation of the reactor for the production of biogas with a capacity of a reservoir 1 m^3 / day and retrieval of data conducted in June - December 2015 on the island of Madura more precisely in the City Bangkalan, the village of Tanah Merah, Desah Dlambah Dajah.

2.2. Stages of Research

This research was conducted through experiments with the stage activities as follows: Preparation of reactor installations for biogas production, preparation of biogas, setup tool absorption/packed column, preparation of research procedures, preparations of the gauges are calibrated, measurement and data retrieval. After that analysis of the data research, writing and reporting of research results.

2.3. Water Boilling Test

In this test, the fuel is used biogas. The efficiency and power from biogas stove are calculated by boiling water test. This test may be determined by the following variables: Wait until the biogas in a container (reservoir) in the circumstances fully. Preparing stopwatch, installing a burner the first, ie, the burners with the diameter of the fire pit 2 mm on the stove. Weigh the water according to the size that has been defined and enter it into the pan. Measure the initial temperature of water (T_1). Measuring the initial use of fuel with a flow meter. Turn stove, retrieval of data for temperature and fuel consumption is done in intervals of 2 minutes until the water boils (T_2). Next, weigh water is left on the pan.

In subsequent experiments then simply replace the burner of the stove with the burner of the second (hole 3 mm) and third (hole 4 mm) and the steps are the same as is done in the first trial.

Figure 2. Experiments with Water BoillingTest.

2.4. The Performance of the Stove Power of Stove

To calculate the amount of power from biogas stoves used the following equation [16]:

$$P = \frac{m_f.E}{\Delta t} \quad (1)$$

where: P is the power of the stove (kW), mf is the fuel consumption during the period of time t (kg), E is the Lower Heating Value (LHV) b.bakar, kJ / kg. bb and t is the time of the test (s).

Efficiency

Efficiency is the ratio of useful heat divided by the heat supplied by the fuel during the test. The equation used is as follows [16],

$$\eta_{overall} = \frac{(m_w.cp+m_{pa}.cp_a)(T_1-T_2)+m_s.H_{fg}}{m_f.E} x100\% \quad (2)$$

where: η is the total efficiency of the stove, mw is the mass of water which is heated, kg, mpa is the mass of the pan used (kg), Cp is the specific heat of water, kJ / kg, Cpa is specific heat pan, kJ/kg, T_2 is the temperature of boiling water °C, T_1 is the initial temperature °C water, ms is the mass of water vapor (kg), mf is the mass of fuel used (kg), hfg is the latent heat of vaporization of water, and E is Lower Heating Value (LHV).

3. Result and Discussions

3.1. Analysis of Power Stove

Data obtained from experiments using a burner with fire pit diameter 2 mm were as follows:

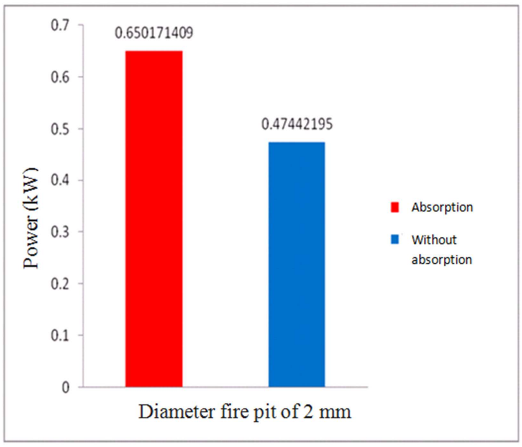

Figure 3. Comparison of the power of the stove for a device that uses the absorption and without absorption with the burner diameter is 2 mm.

By Figure 3 it can be concluded that, overall, the presence of absorption will increase the power of the stove and overall as well with the absorption of substances impurities, which are still present in biogas then biogas becomes purer, so that the calorific value becomes better. This corresponds to the research conducted by [15].

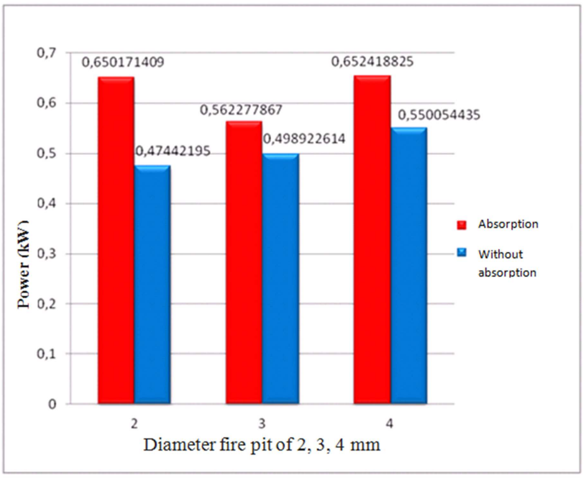

Figure 4. Comparison of power from the stove to the tool using absorption and without absorption for a wide range of diameters burner.

From the picture above it can be concluded that overall the presence of absorption will increase the power of the stove and overall anyway, with their absorption of impurities left on biogas cause biogas becomes purer, so that the calorific value becomes better. In addition, differences in the diameter of a fire pit at the burner also affect the value of power. This is evidenced by the increasing value of the power of the pot, which uses a fire pit burner diameter 4 mm compared with a diameter of 3 mm and 2 mm. This is because with a large-diameter burner, the fuel consumption is needed also great. Based on Equation 1, if the consumption of fuel (mf) increases, the value of the power (P) also increased.

3.2. Analysis for the Efficient Stoves

In the same way, then the calculation of the efficiency obtained in all subsequent experiments by using Microsoft Excel. More results can be seen from the table below:

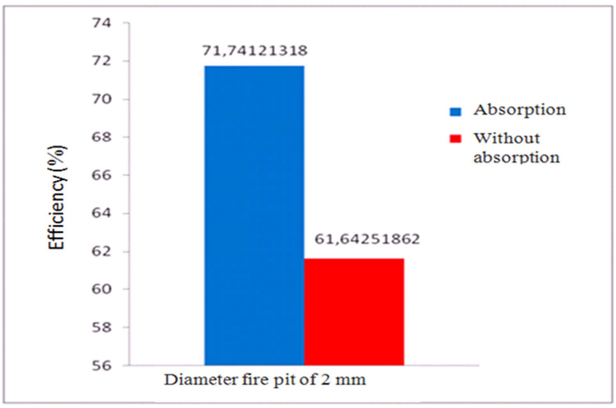

Figure 5. The influence of absorption and without absorption to the efficiency of the burner 2 mm diameter.

In Figure 5 is shown that with the absorption of biogas, the efficiency generated from biogas stove was larger than the efficiency of the resulting biogas stoves without absorption. For absorption efficiency is 71.74% while without the absorption the efficiency is 61.64%. This is due to the absorption occurs purification from impurities CO_2 from the biogas product thus obtained methane (CH_4) pure. Of pure methane gas generated heat is greater than without absorption. This is in accordance with Equation 2.

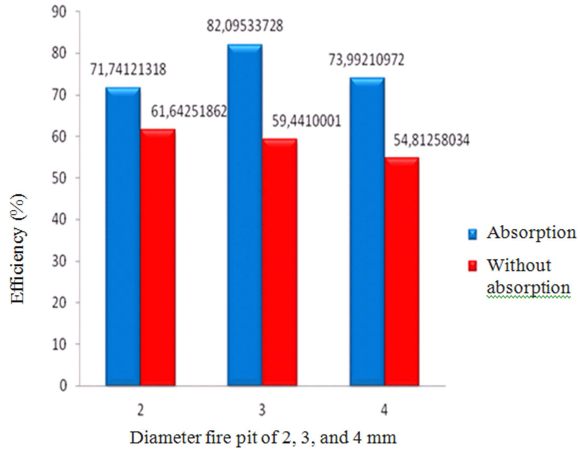

Figure 6. Comparison of efficiency of a biogas stove using the tool absorbs and without absorption for all burner with a diameter of 2, 3, and 4 mm.

Through Figure 6 indicates that, overall efficiency of biogas stove using the absorption is greater than the efficiency of biogas stoves without using absorption. This is caused using absorption, the heat produced is greater than without absorption.

3.3. Analysis of the Mass of Steam Against Time

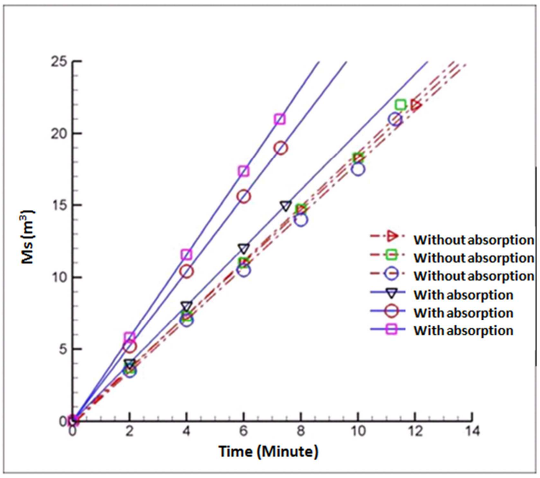

Figure 7. The relationship between the mass of steam (Ms) against time.

From the inside of Figure 7 seen that, with the rise time the mass of evaporated water will further increase. There are interesting things here, namely in the picture the increased difference in mass of steam and shown in a fire pit diameter of 4 mm. The increase in the mass of water that evaporates more quickly than others. This is because with a diameter fire pit on a stove burner which is great then the heat is supplied also getting bigger. The temperature will increase and consequently, the mass of vapor produced is also faster increases. This is in accordance with the equation of latent heat [17] namely:

$$q = Ms. Hfg$$

In the equation when the value of q greater than the value to the vapor mass (Ms) was also great.

4. Conclusions

1. In the experiment Water Boilling Test, using 4 mm diameter burner obtained power of 0.65 kW and for no absorption 0.55 kW. The power is greater than the diameter of burner 2mm and 3mm.

2. Efficiency results obtained from experiments using either absorption or no absorption. For the hole diameter of the burner 4 mm by absorption is 73.99% and 54.81% without absorption. This efficiency larger than the hole diameter of the burner 2mm and 3mm.

3. The fastest time of boiling water is obtained by using a burner which has a diameter of 4 mm over a period of 11 minutes 30 seconds without absoption and 7 minutes 26 seconds with absorption.

Acknowledgments

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