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KESIMPULAN

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DESIGN OF BIOGAS PURIFICATION TO REDUCE CARBON DIOXIDE (CO_2) AND HYDROGEN SULFIDE (H_2S)

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Abstract
Biogas is a gas produced from decomposition of organic matter by microorganisms in anaerobic conditions. The problems that are mainly from the development of biogas technology are the high levels of H_2S and CO_2 in biogas which become an obstacle in the application of biogas directly because it can lead to corrosive components of energy conversion equipment (generator sets) and can reduce the heating value in biogas combustion. The aim of the paper is to design a biogas purification device using Calcium Hydroxide $Ca(OH)_2$, Iron Oxide (Fe_2O_3), Zeolite, and Activated Carbon in the biogas which are designed according to the characteristics of the biogas installation in Indonesia. From experimental results the percentage of methane gas content increased from 52.5% to 90.2% after purification. $Ca(OH)_2$ solution can be used for adsorbent to increase methane gas levels and reduce CO_2 levels in biogas. Fe_2O_3 iron powder can be used to reduce the levels of H_2S content in biogas so that it can increase methane gas content and is safe to use on generator engines. Zeolite and Activated Carbon can increase methane gas levels and reduce the moisture content and CO_2 contained in the biogas so that when the biogas is applied to the generator engine. The power generated in the generator engine using biogas fuel that has been purified is greater than that which has not been purified.

Keywords: *Biogas Purification; Calsium Hydroxide $Ca(OH)_2$;Hydrogen Sulfide (Fe_2O_3); Zeolite; Activated Carbon*

INTRODUCTION

One of the renewable energy sources derived from biological natural resources that are being developed in is biogas energy. Sources of raw materials to produce biogas can be in the form of livestock manure such as cattle, buffalo, pigs, horses and poultry, can also come from organic waste such as food waste, rotten fruit and rotten vegetables. Currently there are many Indonesian people who use biogas as an alternative energy source, especially in the area of cattle farmers. Biogas produced by cattle farmers has great potential in Indonesia. On a national scale, the Lampung region occupies the seventh position for the number of dairy cattle population, so that there are also quite a number of cattle breeding locations in each district/city (Ministry of Agriculture, Republic of Indonesia, 2017). However, the use of biogas still needs to be improved because the technology is a new thing in the community, even though biogas is an alternative energy source that is environmentally friendly, renewable, and can be used as an energy source to drive electricity generators. Biogas is very potential as a fuel because of the methane content produced by microorganisms [1]. Theoretically the content of biogas without purification resulting from anaerobic process consists of the main elements in the form of methane (CH_4) and carbon dioxide (CO_2), and several other elements, such as Hydrogen Sulfide (H_2S), Ammonia (NH_3), Hydrogen (H_2), Nitrogen (N_2), Carbon Monoxide (CO), saturated or halogenated carbohydrates, and Oxygen (O_2). Biogas is very potential as a fuel because of its high methane content which is around 55-65%. In general, the content of the biogas is a mixture of 50-70% methane (CH_4), 30-40% of carbon dioxide (CO_2), 5-10% of hydrogen gas (H_2) and the rest of other gases such as ± 2% H_2S. Biogas has a weight of 20% lighter than air and has a combustion heat value of 4800-6200 kcal / m^3. This value is slightly lower than the burning value of pure methane gas which reaches 8900 kcal /m^3 [2].

Methane gas is the primary element and becomes the main parameter in determining the quality of biogas processing production. Biogas produced from this digester can be used as fuel for cooking, for lighting or for generating electricity with a generator set (generator). So far, new biogas is used for cooking, even though this fuel has the potential to produce electricity with a generator set. If the biogas will be used to fuel the generator engine, the biogas must be purified first to remove impurities so that the methane content increases. The quality of biogas can be increased by several purifications, namely by removing impurity gases in the biogas, especially reducing levels of hydrogen sulfur (H_2S) and carbon dioxide (CO_2), and Particulate Matter (PM). Hydrogen sulfur (H_2S) which is toxic and if inhaled can cause some problems in human health. H_2S gas also causes corrosion in gas storage tanks, compressors and

engines [3],[4]. Carbon dioxide (CO_2) has properties that can inhibit the process of biogas combustion which can reduce the rate of fire propagation caused by molecules of CO_2 inhibiting collision reactions between hydrocarbon molecules and air molecules.

The main reasons for gas purification include the need to meet the requirements of equipment that uses gas fuel (engines, boilers, fuel cells, vehicles, etc.); to increase the calorific value of the biogas and to standardize the quality of biogas. So it is important to show that the quality of the biogas required depends heavily on application [5]. Absorption can take place in two types of processes, namely physical absorption and chemical absorption. Physical absorption is absorption where the dissolved gas in the liquid absorbs without chemical reactions. Chemical absorption is absorption where the dissolved gas in the absorbent solution is accompanied by a chemical reaction.

Several methods have been carried out for the biogas purification process. Harasimowicz, et al (2007) [6] used Polyimide membranes for enrichment of methane gas content N.Tippayawong, et al. (2010) [7] using a solution of $Ca(OH)_2$, NaOH and MEA, to reduce CO_2 and H_2S and produce a reduction in CO_2 levels up to a value of 4 percent. Another method is the reduction of CO_2 and H_2S by using a mixture of white cement Zeolites [8]. The biological oxidation method has also been carried out Montebello et al., (2012) [9] has succeeded in reducing H_2S to 95%. Purification using the absorber method is more effective than the adsorber process because of the greater gas contact with the solution compared to solids [10]. Biogas purification process can be done by various purification methods including chemical absorption using Methyl diethanolamine (MDEA) solution to reduce CO_2 gas [11], while H_2S is eliminated by chemical absorbs using Fe/EDTA catalyst, where H_2S is converted to Sulfur [10]. Biogas purification is also carried out with a condensation system by using several media such as lime and NaOH to reduce CO_2 gas [14]. Several methods have been carried out for the biogas purification process, including the process of reactive absorption of H_2S in biogas by using a Fe-EDTA catalyst solution which results in an H_2S reduction efficiency of up to 80.63%. Another method is to reduce CO2 and H_2S by using activated carbon which results in a decrease in CO2 levels of 35.04% and an increase in CH_4 of 34.01% [13]. The purification method using CaO and water scrubber has also been carried out and resulted in a reduction efficiency of 20.86% and an increase in methane content to a concentration of about 65% [15]

In an effort to increase methane gas levels and reduce impurities, namely Carbon Dioxide (CO_2) and Hydrogen Sulfide (H_2S) gas so that it can be used optimally on gasoline engines, biogas purification is very important to do. Purifying biogas from H_2S gas impurities will result in a more complete combustion process and does not cause corrosion damage to the heat exchanger components used. As for some methods that have been carried out for biogas purification process, there is still no biogas purification that combines adsorption and absorption methods, and the existing materials and construction are still relatively difficult to apply in the area of biogas use in Indonesia. So that in this study a purification device is designed which can work at one time to reduce the gas content of H_2S and CO_2. In some of these methods, there is also no biogas refining that combines the adsorption and absorption methods, and the existing materials and construction are still relatively difficult to apply to areas of biogas use in Indonesia. So that in this study biogas purification equipment was designed by using Calcium Hydroxide $Ca(OH)_2$, Iron Oxide, (Fe_2O_3), Zeolite, and Activated Carbon in biogas which was designed according to the characteristics of biogas installation in Indonesia. The raw materials used for biogas purification are relatively easy to obtain in most biogas users in Indonesia, especially in Lampung province.

MATERIAL AND METHODS

In this research on biogas uses experimental research methods. The object observed in this research is the comparison of the composition of methane gas after purification using adsorbent materials of Calcium Hydroxide $Ca(OH)_2$, Iron Oxide, (Fe_2O_3), Zeolite, and Activated Carbon. Activation process was carried out by soaking the active carbon with 32% HCL solution during the night and then washing it until its originality disappeared (litmus paper color did not change). After being washed, the activated carbon is then heated (oven) at 110 °C for one hour. Whereas for zeolite carried out with the same procedure using 98% H_2SO4 solution. CO_2 gas adsorption process is carried out in the first reactor which is the chemical adsorption process of gas-liquid contact. Biogas from a gas holder that still contains CO_2 is flowed into a solution of $Ca(OH)_2$. CO_2 gas contact with $Ca(OH)_2$ solution will produce $CaCO_3$ deposits. For biogas purification process and collect the necessary data, required tools as follows:

a. Absorber column: used to place the absorbent and pass the biogas to be purified
b. Compressor: used to put pressure on the biogas so that it can flow through the absorber column
c. Gas flow meter: used to measure biogas flow
d. Manometer: used to determine the pressure in the absorber and in the biogas storage tank
e. Venoject: the tube used to place the sample to be tested by gas chromatography.
f. Spuit: an injection used to venoject, enter the biogas sample into venoject and take a sample from venoject.

g. Volt meter: used to measure the voltage generated by the generator.
h. Ampere meter: used to measure the electric current produced by a generator.
i. Gas Chromatography: used to determine the methane content in the biogas before and after the purification process.
j. Gasoline generator 1300 watt: used for biogas testing after the purification process.

This research is an experimental study with a sampling location in Karang Anyar which is a biogas digester location owned by cattle farmers. Samples taken before and after the purification process are tested for their gas composition with Gas Chromatography. The biogas flow capacity that enters the purification device is 0.004 m^3/s; the speed of the biogas flow through the purification device is 0.32 m/s. The performance testing of the generator engine is also done at the location where the sample is taken. Schematically the series of testing tools in this study are shown on Fig.1.

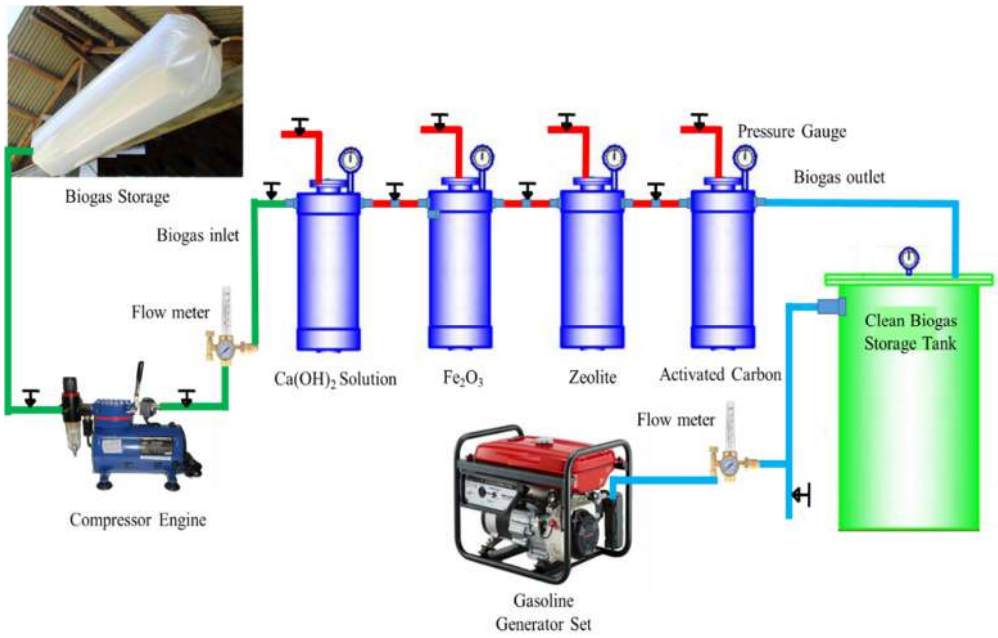


Fig. 1. Schematic diagram of biogas purification

RESULT AND DISCUSSION

3.1 Methane Content Testing

The purification process is the process of absorption of impurities in a compound that can disrupt a process and make it cleaner (pure). In this study biogas is an alternative gas substitute for fossil fuels, the biggest component in biogas itself is methane (CH_4), this methane content is needed in the process of using alternative fuel sources. But not all the contents in the biogas are CH_4, there are still many other gas impurities that can interfere with the combustion process when used later. In this case the researcher conducted a study by reducing the CO_2 and H_2S impurity gas to increase the percentage of methane gas in biogas.

To determine the effect of the use of absorbent on the content of methane in the biogas, then testing with Gas Chromatography. From experimental results the methane content obtained on Table 1.

The results of testing the methane content contained in the biogas shows that by passing the biogas through the absorber column it will cause the methane content to increase compared to the biogas which the absorber column does not pass. The increase in the methane content in the biogas produced depends on the absorbent used. The ability of $Ca(OH)_2$ solution to absorb CO_2 because $Ca(OH)_2$ when mixed with water will form Ca^+ and $2OH^-$ ions like equation (1). Whereas CO_2 when reacting with water will produce H^+ ions are presented on equation (2). So that ion ions dissolved in H_2O will react as in equations (3) and (4).

$$Ca(OH)_{2(s)} \rightarrow Ca^{2+} + 2OH^- \quad (1)$$

$$CO_{2(g)} + H_2O \rightarrow H^+_{(ag)} + HCO_3^-{}_{(ag)} \quad (2)$$

$$HCO_3^-{}_{(ag)} + OH^-_{(ag)} \leftrightarrows H_2O_{(l)} + CO_3^{2-} \quad (3)$$

$$H^+_{(ag)} + OH^-_{(ag)} \rightarrow H_2O_{(l)} \quad (4)$$

Where for CO_2 continuously flowed into a solution of $Ca(OH)_2$ subs reaction, then it will continue to absorb CO_2 which leads to a decrease OH^-. So the results of the overall reaction are shown on equation (5).

$$Ca(OH)_{2(s)} + CO_{2(g)} \rightarrow CaCO_{3(ag)} + H_2O_{(l)} \quad (5)$$

The increase in methane content in the biogas after the absorber column has been passed above is caused by the absorption of other gases contained in the biogas, this can be seen on Fig.2. The content of carbon dioxide will react with a solution of calcium hydroxide so that the percentage will decrease in the biogas, as a result the percentage of methane gas will increase.

Table 1. Test results of methane gas (CH_4) in biogas

Type of absorbent	Percentage of Methane (CH_4) (%)
Without Absorbance	52.5
Adsorbent $Ca(OH)_2$	75,8
Adsorbent $Ca(OH)_2$ and Fe2O3	82,5
Adsorbent $Ca(OH)_2$, Fe2O3 and Zeolite	87,3
Adsorbent $Ca(OH)_2$, Fe2O3, Zeolite and Activated Carbon	90,2

One of the considerations that can be developed to remove H_2S gas from biogas is to consider the use of the absorption reaction by grams or iron powder flakes. With this reaction hydrogen sulfide will be absorbed into iron (III) hydroxide Fe $(OH)_3$ known as bog iron ore or absorbed into iron (III) oxide Fe_2O_3). Using this dry process H_2S is converted to iron (III) hydroxide or iron (III) oxide and water based on reactions 6 and 7:

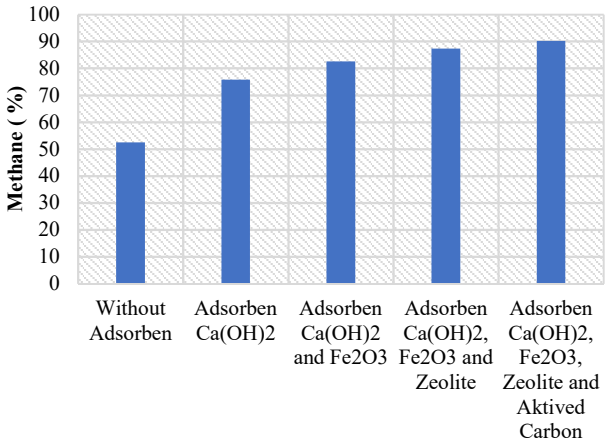
$$2Fe(OH)_3 + 3H_2S \rightarrow Fe_2S_3 + 6H_2O \quad (6)$$

$$Fe_2O_3 + 3H_2S \rightarrow Fe_2S_3 + 3H_2O \quad (7)$$

When the absorber column is filled with Calcium Hydroxide and Fe_2O_3 iron powder it is proven that the methane gas content in the biogas increases. This can happen because Fe_2O_3 iron powder has reacted with H_2S contained in the biogas when the biogas flows through the purification device. Iron and iron powder can be used as an effective material to purify biogas from H_2S gas impurities. By using desulfurizer the biogas can be upgraded to zero content of H_2S impurities that lead to avoid increasing acidity [16] of the lubricant therefore the corrosion in the combustion chamber can be avoided.

Increased methane gas content is also shown in the biogas passed from the absorber column which contains Zeolites. This can happen because the activated Zeolite stone is able to absorb impurity gases present in biogas.

With more and more gases absorbed, the content of methane in biogas will increase. From the observations besides obtaining data on increasing levels of methane after the biogas was passed the absorber column, the smell of biogas after exiting the absorber column was also not like the biogas



which the absorber column did not pass. It is possible that gases containing odors are absorbed in the absorbent used.

Fig. 2. Percentage of methane gas content from each adsorbent

3.2 Performance of Generator Engine with Adsorbent Variations

To determine the effect of passing the biogas through the absorber column if the biogas is used as fuel for the generator, the power produced by the generator is tested. From the testing of the power produced by the generator, the following results are obtained:

Table 2. Generator Engine Power Testing Results

Type of absorbent	Electrical Voltage (Volt)	Electric Current (Ampere)	Electrical Power (Watt)
Without purification	170	1.0	170
Biogas Purification using absorbent $Ca(OH)_2$, Fe_2O_3, Zeolite and Activated Carbon	200	1.5	300

From the results of testing the generator performance as indicated by the voltage, current and electrical power produced by the generator with biogas fuel above, it is known that both the voltage and current produced by the generator is the difference between the biogas which is passed the absorber column with biogas which the absorber column does not pass. This difference in voltage and electric current will automatically affect the electrical power produced.

The electrical power generated by the biogas fuel generator that is passed by the absorber column is

higher than the electricity produced by the generator with biogas fuel which is directly supplied from the digester. This shows that the biogas passed by the absorber column has a greater energy value. This increase in energy value is in line with the increase in methane content in biogas.

The use of the bag gas holder of the biogas was useful during compressing of the biogas in to the gas container because this is make easy to be observed whether biogas available or not during compression. Compressing the biogas reduces the storage requirements, concentrates energy content and increases pressure to the level required overcoming resistance to gas flow [17].

From the tests carried out, the voltage generated by the generator cannot reach its maximum voltage of 220 Volts. This fact can be caused by methane content that cannot reach 100% or it could be caused by improper biogas comparison and air regulation. This makes sense since the energy of the biogas is lower than the gasoline one that is about 6.0-6.5 kWm^{-3} [18]. Therefore, it is still necessary to conduct studies to find an absorber column design that can increase the methane content in biogas which is close to 100% and studies to obtain a system for regulating air flow and biogas to obtain optimal comparison.

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CONCLUSION

Based on the results of the research that has been done, it can be concluded:

1. $Ca(OH)_2$ solution can be used for adsorbent to increase methane gas levels and reduce CO_2 levels in biogas
2. Fe_2O_3 iron powder can be used to reduce the levels of H_2S content in biogas so that it can increase methane gas content and is safe to use on generator engines.
3. Zeolite and Activated Carbon have an important role in increasing methane gas levels and reducing the moisture content and CO_2 contained in the biogas so that when the biogas is applied to the generator engine there will be complete combustion.
4. The power generated in the generator engine using biogas fuel that has been purified is greater than that which has not been purified. The greater the amount of methane gas in the biogas, the greater the electrical power produced by the generator.

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INFORMASI UNTUK PENULISAN NASKAH JURNAL TEKNIK MESIN UBL

Persyaratan Penulisan Naskah

1. Tulisan/naskah terbuka untuk umum sesuai dengan bidang Teknik Mesin.
2. Naskah dapat berupa :
   a. Hasil Penelitian.
   b. Kajian yang ditambah pemikiran penerapannya pada kasus tertentu, yang belum dipublikasikan,

Naskah ditulis dalam bahasa Indonesia atau Inggris. Naskah berupa rekaman dalam Disc (disertai dua eksemplar cetakannya) dengan panjang maksimum dua puluh halaman dengan ukuran kertas A4, ketikan satu spasi, jenis huruf Times New Roman (font size 10). Naskah diketik dalam pengolah kata MsWord dalam bentuk siap cetak.

Tata Cara Penulisan Naskah

1. Sistimatika penulisan disusun sebagai berikut :
   a. Bagian Awal : judul, nama penulis, alamat penulis dan abstrak (dalam dua bahasa : Indonesia dan Inggris)
   b. Bagian Utama : pendahuluan (latar belakang, permasalahan, tujuan) , tulisan pokok (tinjauan pustaka, metode, data dan pembahasan.), kesimpulan (dan saran).
   c. Bagian Akhir : catatan kaki (kalau ada) dan daftar pustaka. Judul tulisan sesingkat mungkin dan jelas, seluruhnya dengan huruf kapital dan ditulis secara simetris.

2. Nama penulis ditulis :
   a. Di bawah judul tanpa gelar diawali huruf kapital, huruf simetris, jika penulis lebih dari satu orang, semua nama dicantumkan secara lengkap.
   b. Di catatan kaki, nama lengkap dengan gelar (untuk memudahkan komunikasi formal) disertai keterangan pekerjaan/profesi/instansi (dan kotanya,); apabila penulis lebih dari satu orang, semua nama dicantumkan secara lengkap.
3. Abstrak memuat semua inti permasalahan, cara pemecahannya, dari hasil yang diperoleh dan memuat tidak lebih dari 200 kata, diketik satu spasi (font size 10).
4. Teknik penulisan : Untuk kata asing dituliskan huruf miring.
   a. Alenia baru dimulai pada ketikan kelima dari batas tepi kiri, antar alinea tidak diberi tambahan spasi.
   b. Batas pengetikan : tepi atas tiga centimeter, tepi bawah dua centimeter, sisi kiri tiga centimeter dan sisi kanan dua centimeter.
   c. Tabel dan gambar harus diberi keterangan yang jelas.
   d. Gambar harus bisa dibaca dengan jelas jika diperkecil sampai dengan 50%.
   e. Sumber pustaka dituliskan dalam bentuk uraian hanya terdiri dari nama penulis dan tahun penerbitan. Nama penulis tersebut harus tepat sama dengan nama yang tertulis dalam daftar pustaka.
5. Untuk penulisan keterangan pada gambar, ditulis seperti : gambar 1, demikian juga dengan Tabel 1., Grafik 1. dan sebagainya.
6. Bila sumber gambar diambil dari buku atau sumber lain, maka di bawah keterangan gambar ditulis nama penulis dan tahun penerbitan.
7. Daftar pustaka ditulis dalam urutan abjad nama penulisan dan secara kronologis : nama, tahun terbit, judul (diketik miring), jilid, edisi, nama penerbit, tempat terbit.