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Simple Conversion Method from Gasoline to Biogas Fueled Small Engine to Powered Electric Generator

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Abstract

The gasoline fueled single cylinder generator engines are well established and available in the market with reasonable price, in the other hand the biogas fueled engine for electric generator is not well established yet. The purpose of this research is to find simple conversion method from gasoline to biogas fueled of the single cylinder four stroke engines. For this purpose, the biogas should be upgraded to the level of zero H_2S impurity and zero level of H_2O content. The carburetor of the gasoline engine was replaced and only component of the mixer of the fuel and air were used. The intake of the biogas fueled should be completed with valve that can be opened automatically by vacuum of the suction stroke of the engine. To increase the performance of the engine, the liquefied petroleum gas (LPG) was added to the mixture up to 80% of biogas and 20% LPG.

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Keywords: biogas; conversion; electric generator; four stroke engine; gasoline; single cylinder

1. Introduction

The difficulty in manufacturing the biogas fueled engine still become a problem that yield in high price of the biogas fueled engine. This make the progress of utilization biogas as a fuel for electric generator engine in developing country is found not as good as in the developed country. Biogas quality

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varies among the region make it difficult to upgrade in to the standard state for fueled the engine. As reported by Osorio and Torres [1], biogas composed of various gases such as methane (60–70%), CO_2 (30–40%), nitrogen (<1%), and H_2S (10–2000 ppm). This various composition make difficult for the user in setting the engine for example to run the electric generator.

The concentrations of the impurities (methane, carbon dioxide, water, hydrogen sulfide, nitrogen, oxygen, ammonia, siloxanes and particles) are dependent on the composition of the substrate from which the gas was produced. However, to prevent corrosion and mechanical wear of the upgrading equipment itself, it can be advantageous to clean the gas before the upgrading [2].

When flowing out from the digester, biogas is saturated with water vapor, and this water condensate in pipelines and cause corrosion. Water can be removed by cooling, compression, absorption or adsorption. By increasing the pressure or decreasing the temperature, water will condensate from the biogas and can be removed. Cooling can be simply achieved by burying the gas line equipped with a condensate trap in the soil. Water can also be removed by adsorption using molecular sieves, SiO_2, or activated carbon. These materials are usually regenerated by heating or a decrease in pressure. Other technologies for water removal are absorption in glycol solutions or the use of hygroscopic salts [2].

During microbiological reduction of sulfur containing compounds (sulfates, peptides, amino acids) hydrogen sulfide is formed. The concentrations of hydrogen sulfide in the biogas can be eliminated either by precipitation in the digester liquid or by treating the gas either in a stand alone vessel or while removing carbon dioxide. Addition of Fe^{2+} ions or Fe^{3+} ions in the form of $FeCl_2$, $FeCl_3$ or $FeSO_4$, to the digester precipitates the almost insoluble iron sulfide that is removed together with the digestate [2].

Beside its difficulty for fueled the engine, biogas has advantages as alternative energy since easy to produce even from municipal waste [3]. This make that the effort to use biogas to fueled the engine should be promoted and supported as what happened in the developed country. Recently the biogas is possible to use for driven air conditioning system [4], and more even at the sub tropical region, the used of biogas was proven well for combined heat and powered (CHP) for establishing electricity and heating during winter [5]. The advantages of biogas plants are varied [6]: economically attractive investment; easily operated and safe installation; production of renewable electricity and heat resulting in a reduction of CO2 emissions; reduction of methane emissions from manure storage and; improvement of fertilizing qualities of manure.

Biogas systems also lead to indirect environmental effects that are not direct results of the replacement of other energy systems. One example that was reduced emission of methane from storage of liquid manure if the manure is used for biogas production. Another example is the anaerobic digestion and biogas production from organic waste materials that are composted. Composting of organic waste causes biological emissions of ammonia, nitrous oxide and methane and these emissions can be significant if gas-cleaning equipment is not used. The digesting of organic waste produces indirect environmental benefits, in the form of reduced emissions of greenhouse gases (methane and nitrous oxide) and pollutants contributing to eutrophication (ammonia), and these indirect effects even exceed the direct environmental benefits of replacing fossil vehicle fuels with biogas. Another important advantage of biogas technology is its application in the treatment of municipal solid waste with a concomitant reduction in the waste volume [7].

It is reported that by increasing the compression ratio in the spark ignition engine could make possible for the gasoline type fueled engine to replace by using biogas, but spark ignition engine operation with biogas containing significant fractions of inert gases such as CO_2 and N_2 exhibit decrease of performance compared with natural gas or gasoline. It is likely that emissions of NO_x will increase [8].

The idea from Rakopoulos and Michos [9] to make a mixture of 15% hydrogen in to the biogas for fuel the spark ignition engine with result the addition of hydrogen in biogas that promotes the degree of reversibility of the burning process mainly during the combustion of the later burning gas, but the contribution of the early burning gas to the decrease in combustion irreversibility with hydrogen addition seems to be less prominent.

Method in mixing biogas with city gas is introduced by the method developed by Yamasaki et al. [10]. It was developed a gas engine system capable of stable operation at any mix ratio of city gas and biogas was developed. The gas engine system consists of a spark-ignition gas engine, an additional electric throttle valve for fuel and control algorithm. The control algorithm was also designed to adjust the fuel and air ratio to attain a higher generation efficiency and lower NO_x emission. It is good for reference to study the previous research conducted by Chandra et al. [11]. The performance results for compressed natural gas, methane enriched biogas and raw biogas at compression ratio of 12.65. The observed power losses due to conversion of diesel engine into spark ignition engine had been 31.8%, 35.6% and 46.3% for compressed natural gas, methane enriched biogas and raw biogas, respectively. The engine test results obtained in terms of brake power output, specific gas consumption and thermal efficiency on methane enriched biogas containing 95% methane has showed that the engine performance is almost similar to that of compressed natural gas. Thus, the gaseous fuel methane enriched biogas is as good as natural gas mix ratios of city gas [11]. Biogas can be used as fuel for natural gas vehicles. The benefit is that fossil fuels like petrol and diesel can be replaced. For biogas, the reduction of green house gas emissions can be as much as 100 %. Natural gas used as a vehicle fuel gives 20-30 % lower CO_2 emissions. A reduction above 100 % can be achieved when biogas produced from manure is utilized as a vehicle fuel. Methane, which is a strong green house gas, is released into the atmosphere from manure in traditional manure storage. Biogas as a vehicle fuel can thus both decrease the leakage of methane from manure and decrease the emissions of fossil carbon dioxide. Another advantage is that vehicles running on upgraded biogas or natural gas have lower emissions of particles, NO_x and SO_x [2].

It is the purpose of this research to develop simple method for conversion from gasoline to biogas fueled small engine, without change the compression ratio of original spark ignition engine. The small fueled gasoline engine was from the specification that easily found in the market of developing country that was 4-stroke gasoline engine, air-cooled, inclined single cylinder. The displacement is 196 cc, with compression ratio 8.5:1. The ignition system was non contact transistor ignition (TCI). This engine was used to run the electric generator.

2. Experimental

The schematic of the process by using 100% biogas is presented in Fig. 1. The biogas obtained from digester was desulfurized by using annealed and compacted steel waste chips from the waste of turning process. The detail process of processing can be accessed in our previous report [12]. The annealed and compacted billet used for this research is presented in Fig. 2.

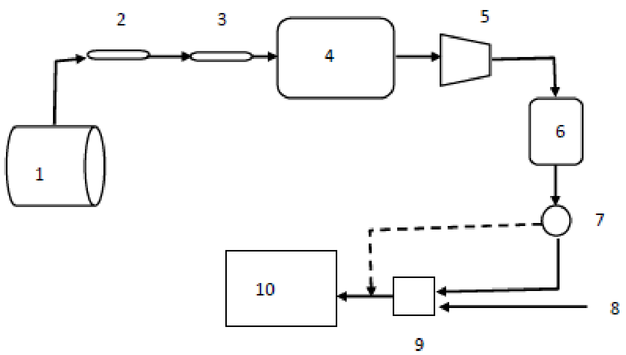

Fig. 1. Schematic of conversion method from gasoline to biogas fueled electric generator engine. 1. digester; 2. desulfurizer; 3. dehumidifier; 4.bag of gas holder; 5. compressor; 6. gas container; 7.vaccum opened valve; 8. air intake; 9. biogas and air mixer; 10. engine.

Fig. 2. Annealed and compacted billet of steel waste chips as desulfurizer.

To ensure that the biogas is free from H_2S impurities, the H_2S content in the biogas was checked before and after passing the desulfurizer. If the H_2S still found in the biogas, the addition of billet of annealed and compacted desulfurizer should be done. The biogas with free impurities of H_2S was flowed to entering the dehumidifier. Again should be ensured here that the biogas should be free from water content.

Afterward the biogas was let to flow in to the bag of gas holder, which from here was ready to be compressed in to the biogas container until reach about 6 bar. The valve that will open by vacuum mechanism was installed to arrange the flow of the biogas. With this valve the gas will flow in to the intake of the manifold and will stop if the engine not runs. The biogas then continues to flow in to the mixer part. This mixer component is part of the carburetor in the gasoline fueled engine but the carburetion cup was replaced and only mixer part is remain. Together with biogas, the air was flowed in to the mixer, and directed in to the intake valve of the combustion chamber. It should be noted here that during starting the engine, the flow rate of the biogas was let maximum and reduce the rate until the engine start running. After that, the rate of air flow in to the mixer was adjusted until the engine run stably.

The composition of CO_2 in the biogas was not in to account in this research since the process for purification of biogas from CO_2 contaminant is complicated for implementation as demonstrated by Chien [13] and also Tippayawong and Thanompongchart [14]. This work also can be used as a proof, that the biogas can run the engine even with still contain CO_2 impurity. The detail schematic for the process is provided in Fig. 3. The selected engine for this purpose was 4-stroke gasoline engine, air-cooled, inclined single cylinder. The displacement is 196 cc, with compression ration 8.5:1. The ignition system was non contact transistor ignition (TCI). It was planned in this research that will not change the specification of the engine for the easy conversion method from gasoline to biogas.

In this research investigation on the effect of mixing biogas with liquefied petroleum gas (LPG) was also conducted. The variations of biogas composition in the mixture of biogas-LPG in this research namely 80%, 85%, 90%, 95% and 100%. The effect of variation of the biogas-LPG mixture on engine speed was then investigated. The schematic of the experimental is depicted in the Fig. 3. The both gas container in the Fig. 3 have the same initial pressure i.e about 6 bar. The valve 11 at the beginning was let full open and the valve 12 was full closed. The engine was then operated, and the engine speed was measured. The experiment then was continued by making a mixture 95%, 90%,85%, and 80% of biogas composition in the mixture by arranging the valve 11 and valve 12 and the engine speeds were measured respectively. The graph of gas mixture composition versus the engine speed was provided.

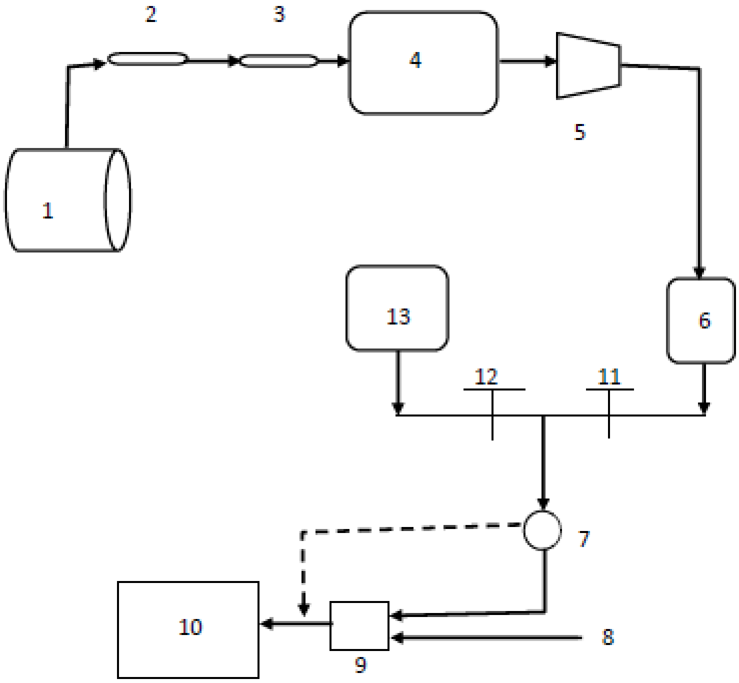

Fig. 3. Schematic of conversion method from gasoline to biogas fueled electric generator engine. 1. digester; 2. desulfurizer; 3. dehumidifier; 4. bag of gas holder; 5. compressor; 6. biogas container; 7.vaccum opened valve; 8. air intake; 9. gas and air mixer; 10. engine; 11. biogas valve; 12. LPG valve; 13. LPG container.

3. Result and Discussion

The conversion methods that was developed in this research was successful to run the electric generator that previously fueled by gasoline to be converted by using biogas. The engine run stable and can produce electricity. The maximum RPM (revolution per minutes) that can be obtained by using 100% biogas was found about 1500 rpm. This makes sense since the energy of the biogas is lower than the gasoline one that is about 6.0-6.5 kWm^{-3} [15]. When The LPG is added to about 5% (95% biogas) in to the mixture, the engine speed was found about 1600 rpm. The engine speed is still not increased significantly with addition 10% LPG which the speed was about 1750 rpm. The significant increase in engine speed was found with addition 15% LPG that yielded about 2600 rpm of engine speed. Finally the engine speed reached its maximum value about 3600 rpm by adding about 20% LPG. The maximum value of the engine speed by using gasoline fuel is 3600 rpm. Therefore to obtained maximum engine speed by using technique developed in this research, the biogas need to be added about 20% with LPG in order to reach the same maximum speed by using gasoline as presented in Fig.4.

By using desulfurizer the biogas can be upgraded to zero content of H_2S impurities that lead to avoid increasing acidity [12] of the lubricant therefore the corrosion in the combustion chamber can be avoided. Previously the existence of H_2S in the biogas was overcome by increased frequency of engine oil change, which will increase the operating cost [16]. Other urgent thing that make H_2S should be eliminated due to H_2S is a Toxic gas [17]. By reducing the water content in the biogas up to zero level affect in easy starting of the engine.

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. It should be noted here that biogas, containing mainly methane, could not be stored easily, as it does not liquefy under pressure at ambient temperature (critical temperature and pressure required are -82.5 ^oC and 47.5 bar). Compressing the biogas reduces the storage requirements, concentrates energy content and increases pressure to the level required overcoming resistance to gas flow [18].

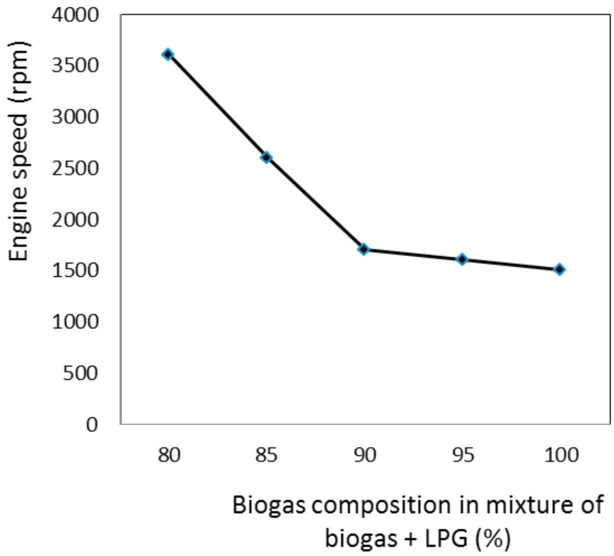

Fig. 4. The effect of composition of biogas-LPG mixture on the speed of the engine.

It is good to suggest here a useful method to reduce the CO_2 impurities in the biogas. A method that is introduce by Mohseni et al. [19]. To increase the biogas yield, the separated carbon dioxide could be used as a component to produce additional methane through the well-known Sabatier reaction. In such process the carbon could act as hydrogen carrier of hydrogen originating from water electrolysis driven by renewable sources.

4. Conclusion

The conversion from gasoline to biogas fueled engine can be achieved by desulfurizing of the biogas at the first step continued with dehumidification and put the gas in to the bag of gas holder. The biogas afterward should be compressed in to the gas container for easy mixing process with oxygen from the air. The carburetion component was replaced and only mixer part of the fuel is used. During starting process, the biogas is let to flow in maximum flow rate and reduce the rate until engine start running. The process is followed by adjusting the air flow in to the mixer until the engine run stably. The engine is running even with still contain CO_2 impurities. To increase the speed of the engine, the liquefied petroleum gas (LPG) is added to the mixture up to 80% of biogas and 20% LPG.

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