Utilization of Exhausted Gas of Engine Generator to Drive Biogas Compressor

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Availability of fossil energy sources is now limited due to high exploitation until now. Biogas is one of alternative energy, which may be developed to solve the energy problem. Biogas is product of the degradation of organic material through the anaerobic digestion process. Biogas consists of methane, carbon dioxide, water vapor, hydrogen sulfide and other gases. Biogas may be used as fuel in a combustion engine as the driving in electrical generators.

Supply pressure of *biodigester* is usually low, so compressor is needed to increase pressure and stabilize the gas supply to the engine generator. Turbocharger which utilizes exhaust gas of Genset can be used to compress biogas. Specification of generator set rated power of 2000 watts (2200 watt peak) with a gasoline engine driver 5.5 HP single cylinder capacity 163 cc. Some adjustments needed in the generator set are on (1) compression ratio, (2) carburizing / mixer, (3) adjusting the spark plug gap, (4) the ignition timing and (5) other necessary treatments.

Results show, that the turbine speed achieved 70,000 rpm during cold test using pressurized air 7 bars. A compressor output pressure 65 cm-water-column is achieved during unloaded hot test by engine speed of 4000 rpm. Results of test with biogas fuel show, which output power of generator, achieved 1700 W by test using turbocharger and 1200 W without turbocharger.

Keywords: biogas, gen-set, turbocharger, exhaust gas, coupling system

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A. INTRODUCTION

In the vision of new and renewable energy, announced the government, the composition of the target by the year 2025 is 32% of primary energy balance of natural gas, 23% coal and 20% petroleum, while the remaining, 25% comes from new energy, renewable energy and energy from biological resources (ESDM, 2005).

Efforts to search and manage alternative energy sources that can replace fossil energy is urgently needed. There are several types of alternative energy that could be used, such as, biological resources that can be converted into biofuels (biogas, bioethanol and biodiesel), renewable and produce much lower carbon emissions than those of fossil fuels (Wakid, 2009).

Utilization of biogas for engine fuel has not been done, while it is possible to use biogas as a fuel for engine as the mentioned in theory that methane gas content is the dominant element in biogas and almost equivalent to natural gas. In practice the methane gas content varies depending on various factors such as: the design of the digester, the content of the substrate, handling and so on (Junus, 1995).

Biogas as fuel is used directly by utilizing the natural pressure of the digester, in certain situations however, will occur a pressure drop that causes generator sets work bothered or even lose power / off. The utilization of biogas by using additional pressure is done by electric compressors, electric compressors require the use of electrical energy from the generator. Electrical energy generated should be used for other needs outside the system of generator sets itself.

It takes a compressor without using electrical energy as its driving force, for example by utilizing the exhaust gas flow from driving motor. Engine exhaust gas residual heat is the engine combustion process distributed into the air which contains kinetic energy and heat in the form of hot gas stream.

The objectives are to determine the feasibility of the turbocharger compressor to compress and flow biogas energy by utilizing exhaust gas from the combustion engine. The parameter is the optimal biogas pressure of the *turbocharger* for biogas from the digester to drain tube stabilization (temporary storage).

This study is considered urgent because it is applicable, as the company needed in the field for the biogas user community for electrification are often troubled by the pumping system. It is expected to improve the efficiency of the use of biogas as an alternative fuel.

The conversion of fuel to biogas in *Otto* engine requires some modifications including the fuel intake system, and the *ignition timing* changes. The change in the engine system is based on the difference of *Otto* fuel . One of them is the higher octane value in biogas so earlier ignition timing (advance) is needed to get better performance.

Muhkamad Wakid (2009), conducted a study on 800 watt generator fueled biogas with methane content 35.24% per volume, electrical power generated 440 watts by biogas flow 735 L / h, the net heat rate (NHR) 18.959,1773 BTU / kWh, brake mean effective pressure (BMEP) 249,43 kPa, and the overall efficiency 18%.

Research was also conducted by Ashrf Abdel-Galil, et al, (2008) on the gasoline engine (spark ignition) single cylinder 4 stroke, capacity143 cc , rate power 3.3. fueled by biogas with 69.6% methane content, calorific value of 29.360,7 kJ/m3. Store the biogas from the digester into an inner tube car tire, pumped using an electric compressor. Compressor specifications : max. pressure 60 psi, capasity 0,00025 m^3 / up to 25 psi. Compared to gasoline fuel consumption biogas fueled is lower with average of 80.3%.

Fudipramono and Adang (2008) study of an experimental study of the influence of variations in ignition timing on engine performance with a constant rotation Otto biogas fuel. Variation in ignition timing at 22 , 24 , 26 and 28 BTDC at which ignited gasoline engine with biogas.

Kapadia (2006) research on fuel gasoline engine with 100% biogas with methane content of 60% and 75%. Performed at 10 kW engine matches: 11 m3/hr biogas input

Biogas Fired Otto Engine

Otto engine also known as spark ignition engine or a gasoline engine as well as four strokes engine which is in general use gasoline (premium) and has a four stages duty cycle . Duty cycle of the engine in Figure 1 (a) intake stroke, when the piston moves from TDC (top dead center) to BDC (bottom dead center) and the suction valves holes open so the air that have been mixed with fuel can flow to fill the cylinder, (b) compression stroke , the piston moves from BDC towards TDC while the valve is closed, causing compression process, (c) expansion stroke, where the fuel air mixture that has been compressed in the previous step get burned triggered by the spark plug, causing heat and high pressure, piston driven from BDC to TDC, and (d) exhaust stroke , the piston moves from BDC to TDC while the exhaust valve open to remove the exhaust products of combustion gases.

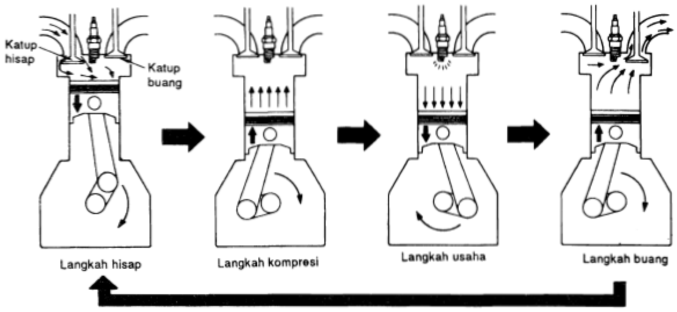


Figure 1. Otto combustion cycle motors work (Toyota, 1994)

Combustion process in the engine requires three main elements: (1) a mixture of air and fuel is homogeneous, (2) sufficient compression pressure, and (3) heat or sparks as a combustion trigger with the precise timing. When all three elements are met then it will generate heat and high pressure that can be converted into rotary motion by the piston and crank mechanism.

Gasoline engine is relatively the easiest engine to convert into biogas fuel, in condition the content of biogas is equal to natural gas. Conversion of biogas fueled engines require some adjustments as follows: 1) Pressure compression 2) Carburizing/Mixer 3) Setting the spark plug gap 4) Ignition Timing and 5) Maintenance required (Walsh, 1988).

Modification aims to increase the number of biogas into the engine or to limit the amount of air. Carburetor adjustment to get the maximum efficiency is a hard duty (Walsh, 1988).

The working principle of the mixer / sprayer is similar to a conventional carburator system, i.e. as a tool to mix air and fuel becomes homogeneous in order to make the combustion process runs well, the basic principle of the mixer / sprayer components is shown in figure 2.

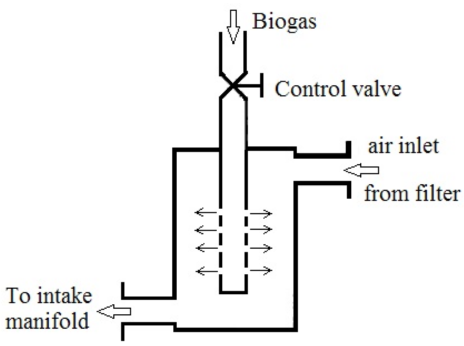


Figure 2. Working principle of the mixer / sprayer (Mitzlaff, 1988)

Modifications to the fuel system for gasoline engines as recommended by Mitzlaff (1988) are two alternativesFirst is providing a nozzle as biogas supply line and the outlet point placed in centre of venturi.(see figure 3a) and the other one is by making the several bores in the venturi circle as an outlet of biogas(see figure 3 b).

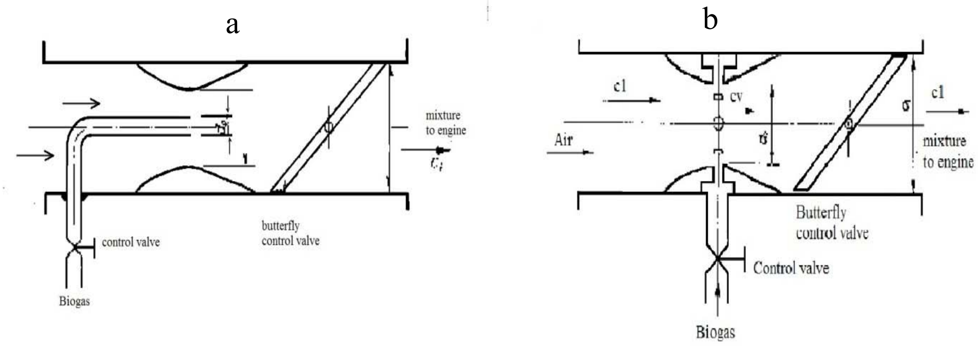


Figure 3. The design of the mixer / sprayer for single fuel (Mitzlaff, 1988)

Recommended fuel pressure requirement will vary between 2-20 psig for naturally aspirated engines and 12-20 psig for turbocharged engines. Caterpillar also recommends providing engine air intake at a rate of 3 ft^3 per engine horse power (Walsh, 1988).

Another alternatif to increase the pressure of biogas supplay could be generated using turbocharger. Turbocharger works by utilizing the exhaust gas flow, then mounted in the exhaust gas line (Exhaust Manifold). Basically turbocharger consists of two main components, (1) turbine unit rotated by the exhaust gas flow, and (2) compressor / impeller unit rotated by the turbine, sucking and compressing gas. Turbine and impeller shaft is coupled.

Operation of the turbocharger mostly depends on the speed of the exhaust gas flow in the exhaust manifold. When the engine runs at low speed, the flow of exhaust gas drives the turbine slowly, and when the engines runs fast the turbine rotates in high speed. Turbo lag occures depends on the weight of the turbine itself and its load. Generally, maximum default boost can achieve at 0.25 to 2.0 bar. (Garrett et al, 2001).

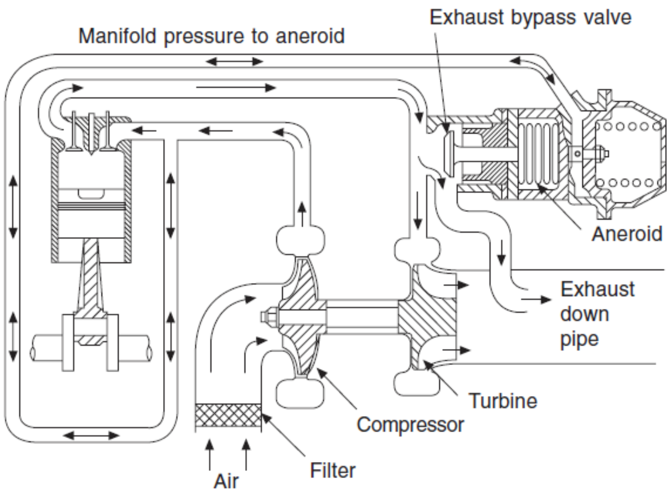


Figure 4. Air flow in the turbocharger system
(Garrett et al, 2001)

Exhaust gas temperature at normal conditions reaches 700 ° C (Garrett et al, 2001). If the exhaust gas pressure increases sharply, the turbine will rotate at very high speeds and excessive pressures on the outlet of the compressor will occure. So, a safety system to prevent damage in the form of exhaust gas overflow (wastegate) is made. Overflow channel is controlled by a diaphragm mechanism which is connected to the compressor outlet. Compressor outlet pressure is used to push the diaphragm open the overflow valve, as shown in Figure 4.

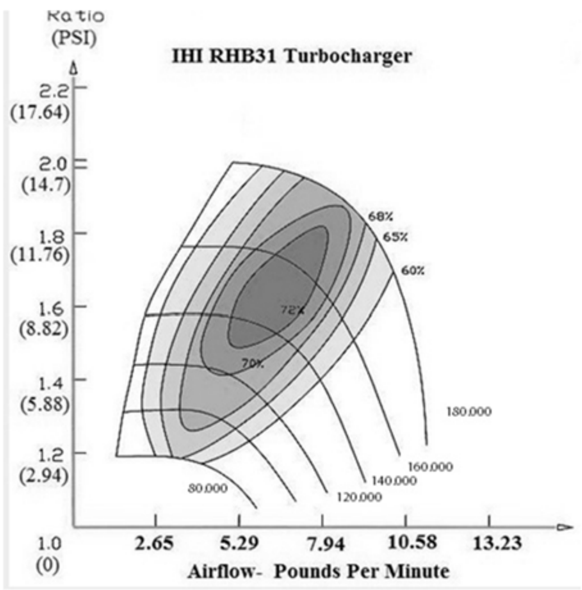


Figure 5. Compressor map IHI RHB-31
(scooterinvasion.net)

Compressor used in this research has specifications describing in the figure 5. Vertical line shows the ratio of pressure between the outlet channel with the inlet channel (pressure gauges / gauge), while the horizontal line in the chart shows the mass flow rate in units of lb / min. The island in the graph shows the efficiency and working of compressor.

B. METHODOLOGY

Exhaust gases produced by the engine generator sets accounted for 35% of energy from the combustion process in the cylinder and the gas pressure is sufficient to drive a turbine in turbocharger to pump, and compress biogas. To support the performance of the biogas fueled engine require some modifications such as ; the higher compression ratio, fuel lines system, spark plug gap setting, advancing the ignition timing and exhaust gas pipe line mounted in biogas compressor (turbocharger).

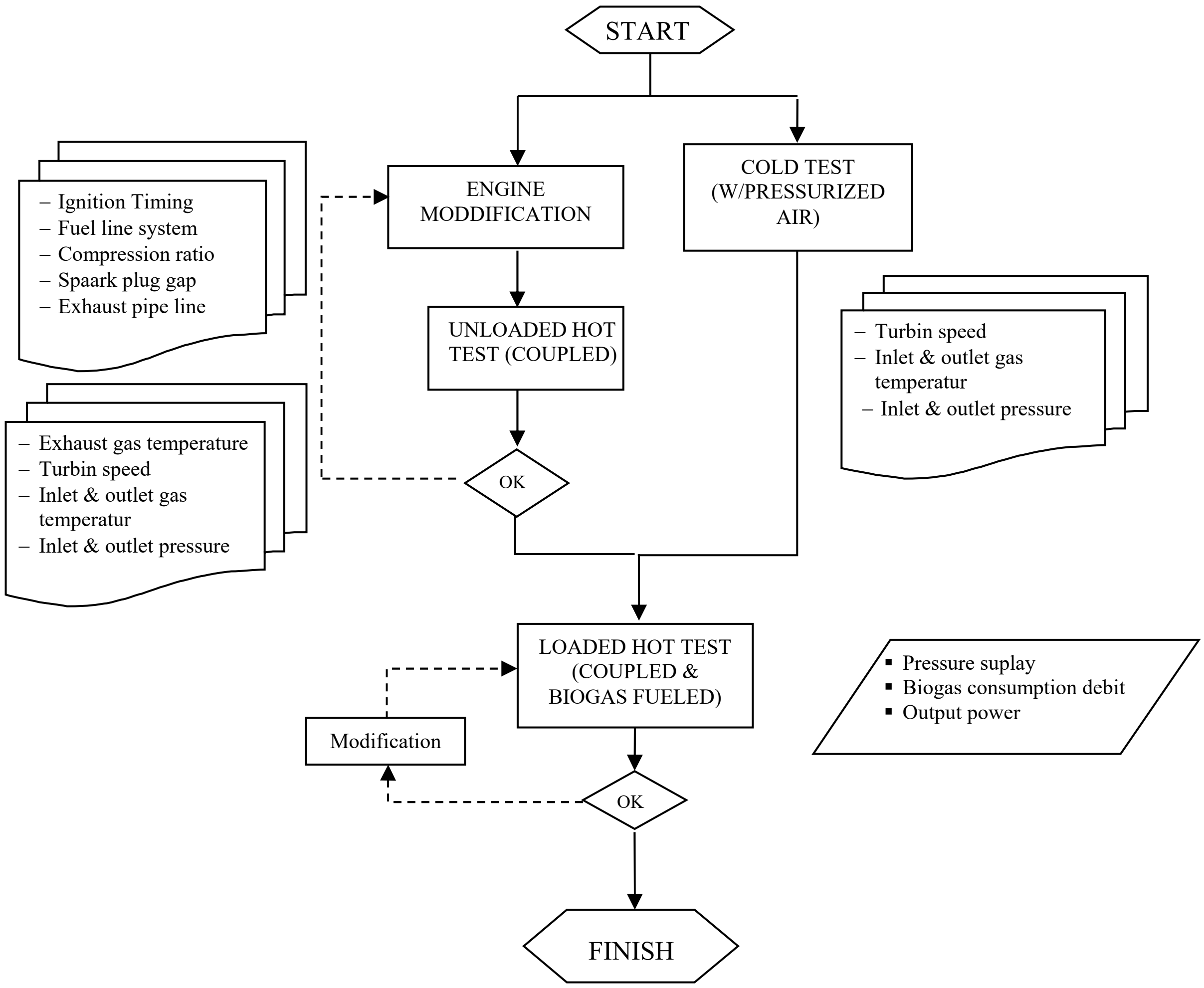


Figure 6. Research Flowchart

The experimental test carried out in 3 stages, 1) The first stage is the cold test is to test turbocharger with variable pressured air to determine the characteristic of the turbine, as measured paremeter : turbine speed (rpm), inlet and outlet pressure, inlet and outlet temperature , 2) the second stage is unloaded hot test to test the compressor driven by exhaust gas without load to determine the characteristics of compressor driven by exhaust gas, the parameter is: engine speed, exhaust gas temperature, inlet and outlet pressure and inlet and outlet temperature, and 3) the loaded hot test to determmine the performance of the generator set coupled with turbocharger, the parameters: engine speed, fuel consumption flow, inlet and outlet temperature of the compressor, the compressor inlet and outlet pressure , based on the output load of the generator.

Tests carried out in stages aimed at security and safety as the objects are methane gas and high temperatures. Methane gas is a gas that can be burned automatically at temperatures above 580 °C, so it required special handling.

The cold test is conducted by giving pressurized air to the turbine gradually to obtain information on the influence of gas pressure generated by the turbine rotation.

Unloaded heat test is conducted to obtain information about turbines ability to produce rotation of the engine which has a fairly low speed engine between 3000-3500 rotation per minute. The test shows the compressor ability to flow biogas and its temperature.

The concept design is installing turbocharger as biogas compressor with a driven by exhaust gas of generator driver shows in Figure 7.

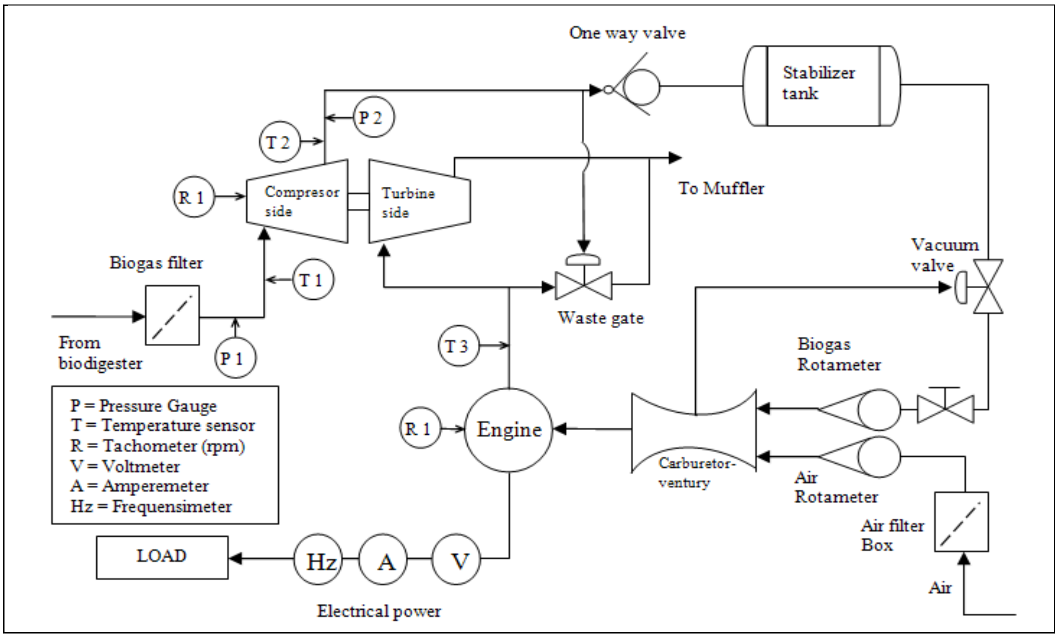


Figure 7. Installation design concept

The tools used in this study are:

- Generator set driven by 4 strokes stationary petrol engine, output power 2 kW that has been modified into biogas fueled engine.
- Turbocharger as biogas compressor utilizing exhaust gas engine.
- Vessel gas storage (stabilization tank) and a pressure regulator.
- Flow meters to measure fuel flow and air flow.
- Manometer to measure the pressure
- Tachometer to measure engine speed and turbocharger impeller speed.
- Ammeter, voltmeter and Hertzmeter to measure the output current, voltage and frequency power.
- Thermometers and thermocouples to measure the temperature of the exhaust gas, biogas temperature at the compressor inlet and outlet.
- Power load in the form of a lamp bulbs.

C. RESULTS AND DISCUSSION

The turbines speed at the highest nozzle pressure at 70 bar is 70,000 rpm (see Figure 8). Highest speed on the test is still under the minimum Compressor map (Figure 6) provided by the manufacturers which is 80,000 rpm. This occurs because the compressor is used specifications for the engine with a capacity of 650 cc, while the engine of genset is 163 cc .

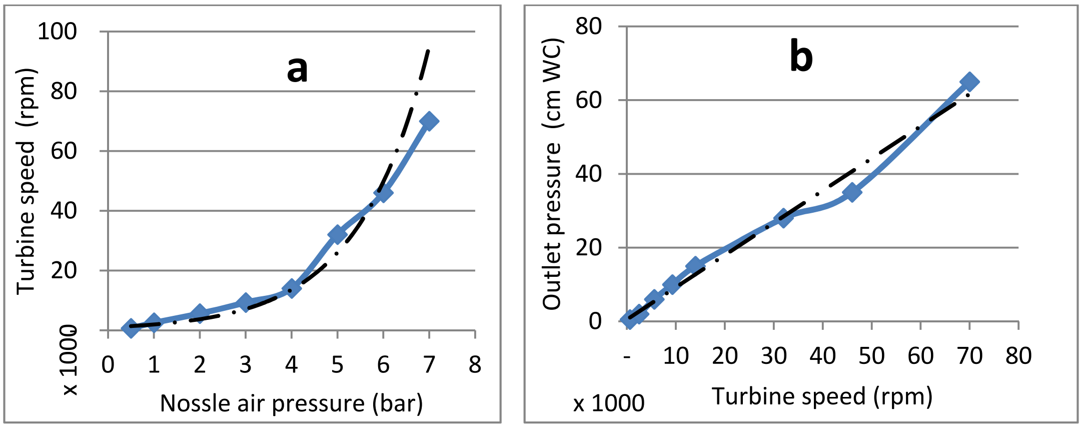


Figure 8. (a) air pressure nozzle to the turbine wheel, (b) rotation of the turbine compressor outlet pressure.

Compressor air pressure generated at the highest speed was 65 cm of water column.

The figure 9 show the characteristics of turbocharger, which described the rotation speed of compressor prosduced by speed of engine.

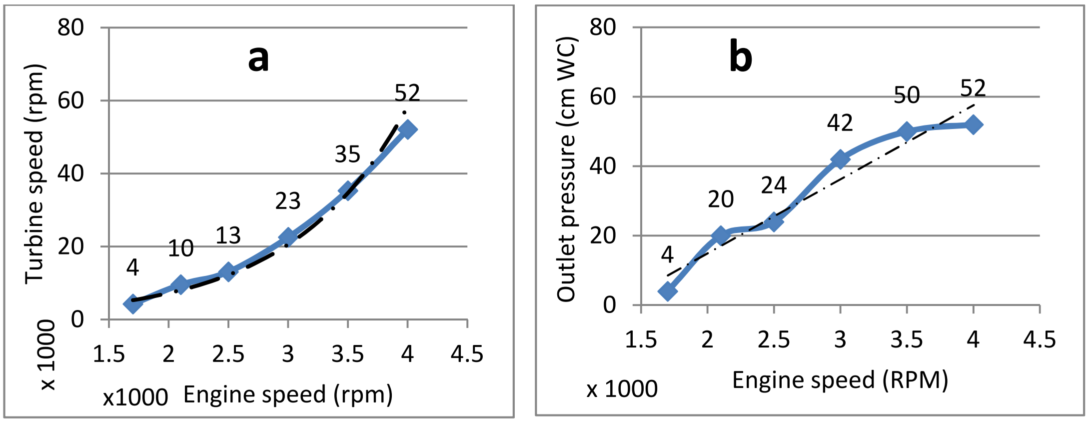


Figure 9. (a) the engine speed of the turbine wheel (b) engine speed on the compressor outlet towards outlet pressure unloaded heat test

Highest engine speed at 4000 rpm produces turbine speed at 52,000 rpm which is far under the minimum standards of the compressor map (Figure 6). The pressure on the outlet about 52 cm water column at the highest engine speed is 4000 rpm, while at work speed 3000-3500 rpm reached at 42-52 cm water column .

Loaded heat test results is shown in Figure 10.

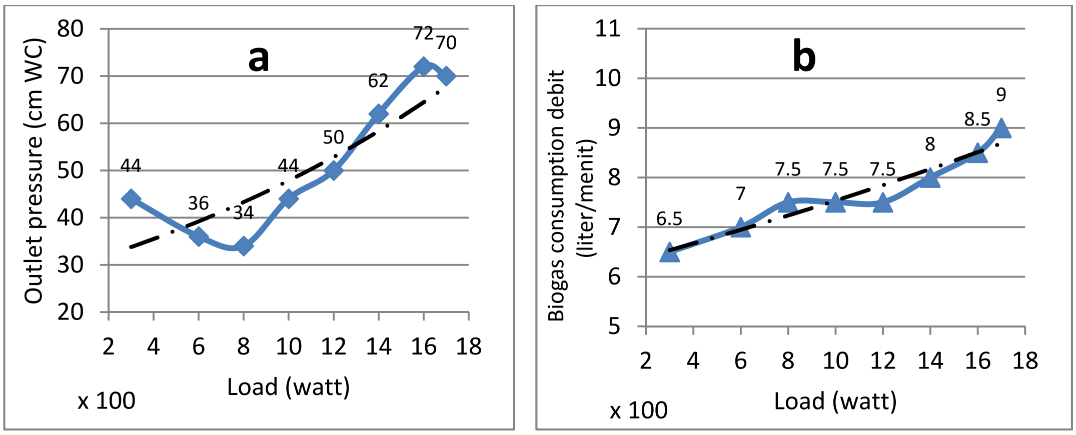
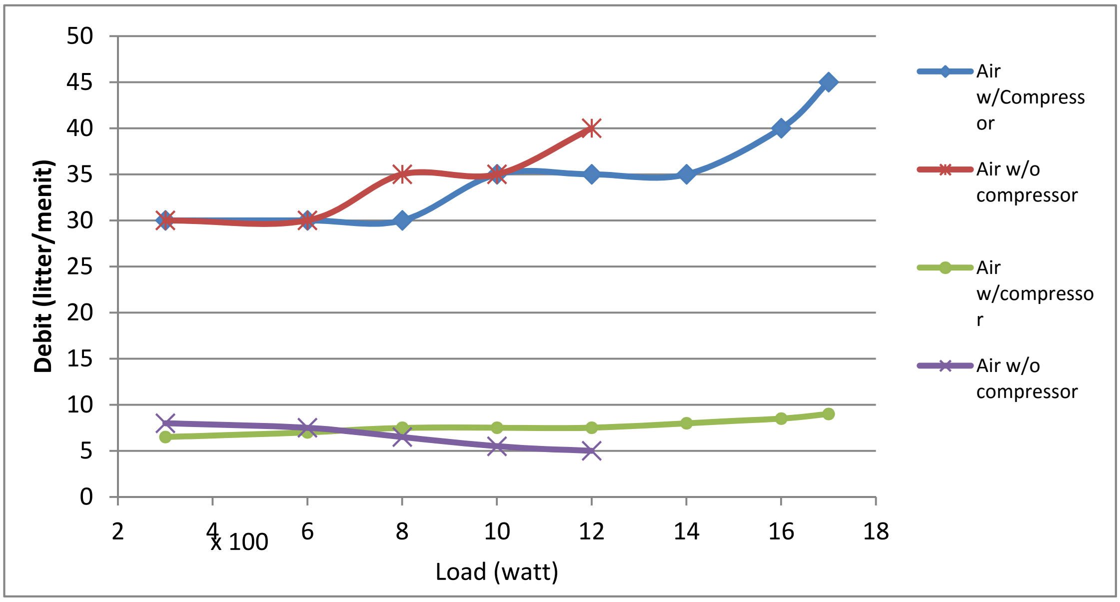


Figure 10. (a) the power output load towards compressor outlet pressure, (b) the power output load towards biogas consumption on heat and loaded test.

Biogas pressure of the compressor has fluctuated, at 300 watt load until the 800 watt has decreased, while at 1000 watts load biogas pressure has increased. Fuel consumption tends to increase gradually depends on the given load.

In order to know the performance of the generator coupled to a compressor driven by exhaust gas, comparative data is required by conducting the test to the same genset without a compressor.



Picture 11. Comparison of debit consumtion biogas and air on engine between coupled and uncoupled compressor.

Figure 11 shows the consumption of biogas in the generator without the compressor decreased on the rising load level, while air consumption increased. So the air fuel ratio become lean mixture and at over 1200 watt generator can not work normally. At the generator coupled with the compressor the load can be achieved up to 1700 watts with a good performance.

D. Conclusion

Applications having a compressor turbocharger in generator is possible to be developed, although the maximum fuel pressure produced under minimum pressure in otherwise require in the theory that 2-20 psi, is 65 cm of water column equal to 0.92 psi. Fuel pressure is not mentioned specifically in the capacity of a particular engine. But when seen from the test data shows the performance improvement of 500 watts of 1200 watts at the same generator is coupled with no compressor. It shows the change in the increase in power at generator

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