PERFORMANCE EVALUATION OF A DIESEL ENGINE USING BIOGAS FROM LOCALLY DEVELOPED PLANT

Department of Mechanical Engineering

A Thesis & Project By

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This thesis submitted to the Department of Mechanical Engineering, Sonargaon University (Su), Dhaka-1215, Bangladesh In partial fulfillment of the requirements for the award of the degree of BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

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STUDENT'S DECLARATION

We hereby declare that, these thesis paper has been done by under the supervision of **Prof. Dr. Md. Alamgir Hossain** Dean, Faculty of Science & Engineering, Sonargaon University (SU). The work presented here in this project report has been carried out by us and has not been previously submitted to any University.

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CERTIFICATE OF SUPERVISOR

This is to certify that thesis paper on "*OPERATION OF A BIOGAS/DIESEL DUAL-FUEL ENGINE FOR ON FARM ELECTRICITY GENERATION TO SAVE DIESEL*" has been prepared as a part of completion of the BSc in Mechanical Engineering program from Department of Mechanical Engineering, Sonargaon University (SU) carried out by [Md. Kabir Ahmed; bme1901017227] [Mehedi Hasan Khan; bme1901017304] [Md. Shamim Reza; bme1901017651] [Md. Aminur Rahmam Mollah; bme1901017547] under my supervision. The report or information will not be used any other purpose.

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ABSTRACT

The idea of biogas as a diesel fuel substitute is not new. It is a very attractive alternative, especially in countries rich in agricultural products and poor in petroleum resources. It can be concluded from the study that while running a diesel engine in dual fuel mode on diesel and biogas saved almost 40% to 45% diesel fuel. Bio gas was used in a single cylinder, direct-injection, compression ignition engine, which has been modified to operate under dual-fuel condition to generate electricity. The primary fuel is biogas, which is ignited by a pilot diesel liquid injection. It is therefore recommended that fixed dome biogas digester may be installed in such agroecological zones like Islamabad.

As the price of diesel is rising in the global market at present, this dual fuel system will help the Bangladesh firms to reduce costs and increase production by saving diesel.

KEYWORDS: Biogas, fixed dome digesters, diesel engine, farm electric generation, dual fuel, save diesel, engine cooling system

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In the name of Allah, the most gracious and the most merciful. Fast and foremost, we are thankful to almighty Allah for giving us the strength, knowledge, ability and opportunity to undertake this study and complete it satisfactorily.

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CHAPTER-01

Introduction

Energy demand in Bangladesh is high and growing as a direct result from economic development and population growth. A large proportion of the country's energy imports is from foreign fossil fuels. It is important to identify alternatives for partial or total substitution of domestic, industrial and transportation fuels. Alternative energy sources must be economically feasible and environment friendly. Among the many different types of alternative energy, biogas from the bacterial biodegradation process of animal manure waste, waste water or solid waste under anaerobic condition proves to be one of the most promising choices. With a current growth of livestock business in Bangladesh, it is estimated that about 3.2 Mt of dry matter of animal manure per year is recoverable. Anaerobic digestion of animal manure in biogas plants for energy, fertilizer supplement and sanitation has made a significant impact for livestock production business as well as rural development. Harnessing this renewable energy source is encouraged through attractive incentives on the tariff and subsidy from the Bangladesh government.

1.1. Dual Fuel Engine:

Engines that can operate using a mixture of two different fuels are called dual fuel engines. Frequently, diesel and gas fuels are used together within dual fuel engines.

The topic of decreasing dependence on imported oil is a recurring issue. Emission regulations and a renewed push for clean technologies are at the forefront of many government initiatives. With diesel fuel prices rising and increasing regulation on emissions, many diesel genset owners and operators are searching for an alternative to conventional fuel. Modern dual-fuel systems with electronic controls that enhance system performance represent a viable answer to growing concerns about the widespread installed base of diesel engines

Since a diesel engine is a compression ignition engine and does not have a spark-plug-type ignition system, the primary diesel fuel is used as the ignition source or pilot ignition for the mixture in the combustion chamber. Therefore, dual-fuel engines retain the fundamental principles of diesel engine operation and the efficiency of the diesel engine compression ratio while enabling the engine to run on a cheaper, cleaner fuel.

Beyond gas and diesel, some dual fuel engines can also use varying mixtures of biodiesel, landfill gas, **bio-gas** and other fuels.

1.2. Why Choose Bio Gas:

Bio gas is renewable gas. We get this gas for free from nature in a special process. Initially some money is required but later money is not required. So it can be said that this gas does not require money every day. That is why we can benefit financially if we use this gas. That As we are getting large amount of biogas from farm waste so we can use this bio gas as dual fuel system on engine to operate & save the diesel.

1.3. Requirements of a Dual Fuel Engine:

Dual fuel engines operate on a primary (main) fuel and a secondary (pilot) fuel. The primary fuel source is typically a gaseous fuel such as hydrogen or bio gas or natural gas, which is injected into the intake manifold.

1.4. Dual Fuel System History:

In a patent application filed on April 6, 1898, Rudolf Diesel proposes that "if a given mixture is compressed to a degree below its igniting-point, but higher than the igniting-point of a second or auxiliary combustible, then injecting this latter into the first compressed mixture will induce immediate ignition of the secondary fuel and gradual combustion of the first mixture, the combustion after ignition depending on the injection of the igniting or secondary combustible". This patent entitled Method of Igniting and Regulating Combustion for Internal Combustion Engines was accepted in 1901 and marks one of the initial efforts to introduce and successfully ignite a less reactive gaseous fuel in a 4-stroke internal combustion engine using a second fuel. Similarly, today, the ability to ignite a premixed charge (ex: air and a low reactivity fuel such as natural gas) with a secondary high reactivity fuel (such as Diesel) or interchangeably solely operating on the high reactivity fuel is one of the important characterization of a dual-fuel combustion strategy.

For several years, the dual-fuel engine was not used commercially due to its mechanical complexity and rough running caused by auto-ignition and knocking. The first commercial dual-fuel engine was only produced in 1939 by the National Gas and Oil Engine Co. in Great Britain. The engine, fueled by town gas or other types of gaseous fuels, was relatively simple to operate and was mainly employed in some areas where cheap stationary power production was required. During the Second World War, the shortage of liquid fuels attracted further interest in dual-fuel engines from scientists in Great Britain, Germany and Italy. Some diesel engine vehicles were successfully converted to dual-fuel and the possible application of dual-fuel engines in civil and military areas were also explored. Different kinds of gaseous fuels, such as coal gas, sewage gas or methane (**Bio gas**), were employed in conventional diesel engines during this time. After the Second World War, due to economic and environmental reasons, dual-fuel engines have been further developed and employed in a very wide range of applications from stationary power production to road and marine transport, including long and short haul trucks and busses.

In 1949, Crooks, an Engineer at The Cooper-Bessemer Corporation—one of the main engine manufacturers during World War-II, presented experimental work with a dual-fuel engine that claimed to have led to the most efficient engine known with a thermal efficiency of 40% at full load. He further highlights that the dual-fuel engine has led to “an extremely economical source of power having an extremely low maintenance cost”. The potential of utilizing relatively cheap gaseous fuel resources and simultaneously benefitting from high thermal efficiencies have promoted the conversion of a conventional compression ignition engine to dual fuel operation. Nevertheless, important limitations still persist: (i)at high loads, the power output and efficiency was limited by the onset of autoignition and knock with most common gaseous fuels, (ii) the combustion process in dual-fuel engine is highly sensitive to the type, composition, and concentration of the gaseous fuel being used, and (iii) at light load operation, the dual-fuel engine exhibits a greater degree of cyclic variations in performance parameters such as peak cylinder pressure, torque, and ignition delay.

A great deal of research Is still being undertaken to understand and overcome the challenges associated with the operation of dual-fuel engines. A promising endeavor consists of successfully harnessing the benefits of the dual-fuel engine in the automotive industry.

1.5. Problem statement:

Running the engine in a dual fuel system with bio gas diesel has been proven to reduce diesel consumption but this approach has some problems. In this method, the temperature of the engine is little higher besides carbon accumulation in the piston, engine head, valves and exhaust manifold. While biogas with 90% methane gives the highest exhaust temperature among all diesel biogas dual fuel runs there no clear relationship is observed between methane content and exhaust temperature for the other cases. This is possibly because CO_2 has two conflicting effects on biogas combustion: it tends to reduce the temperature by dilution effect, while it also extends the duration of combustion and hence the temperature of expelled gases.

So causes problems in engine start after 600 hours.

1.6. Objective:

Economic benefits: With the cost of diesel fuel rising, and dual-fuel engines considerably reducing diesel fuel usage, converting an engine to operate primarily on a cheaper gaseous fuel is economically attractive. In addition, spark plugs and an ignition system are not required, eliminating the costly spark plug maintenance associated with traditional natural gas engines, which helps to further reduce overall cost of operation. Depending on the expected number of running hours and the cost of diesel and gaseous fuels, the up-front installation cost of retrofitting an existing diesel engine to dual-fuel operation can be recovered quickly.

Environmental benefits: Bio gas fuels and natural gas in particular are much cleaner than diesel. Diesel engines that have been converted to dual-fuel operation have exhibited significant reduction in NOX and CO2 over their original diesel operation. This is even more important in areas with increasingly tough emissions regulations. In addition, on-site diesel storage capacity can be reduced.

Technical benefits: Retrofit systems can be installed in the field quickly, minimizing engine downtime. No modifications are required to the core engine or to the factory fuel management system. With the engine's main fuel becoming gaseous fuel rather than diesel and the electronic control system maximizing fuel efficiency, installing an alternative fuel system enables the on-site diesel supply to last much longer, extending engine uptime without compromising performance. Replacing diesel fuel with bio gas typically extends engine maintenance intervals and overall engine life.

For example, life expectancy of cylinder-head valve seats is improved due to the cleaner combustion that gaseous fuel exhibits over diesel. Benefits of the factory diesel engine, including hardware ruggedness and operational efficiency, are maintained. Returning to operation on 100% diesel fuel is possible at any time.

Safety: Bio gas is an easily ignited volatile fuel but diesel fuel is less volatile. Bio gas's narrow range of flammability is also an important safety aspect. Bio gas burns in concentrations between 5% and 15% only. Making accidental ignition highly unlikely. Most importantly, Bio gas does not detonate in an open environment. Finally it can be said that dual duel system of bio gas and diesel is very good and safe in a farm electricity generation.

1.7: Conclusion:

Dual fuel engines reduce the environmental impact of oil and gas operation. Bio gas is often dubbed as 'the bridge to the renewable future' in electricity generation markets. A dual-fuel engine always uses some liquid fuel for starting the combustion process. Dedicated dual-fuel engines can use less than 1% of liquid fuel and instantaneously switch over from liquid-fuel operation to gaseous-fuel operation and vice-versa under load conditions. There are many small & medium farms in rural township they play a role in the economy of a country. So if they produce electricity through this method they will benefit a lot and the electricity demand of the country will be reduced a little.

Chapter-02

Literature Review

2.1: Introduction:

The world's primary energy resources such as crude oil, natural gas, coal and nuclear fuel are not renewable. Their rapid depletion, consequent rise in prices, increased global energy demand and concern for environmental protection have driven the quest for alternative, renewable sources of energy like hydro energy, solar energy, wind energy and biofuels. Petroleum reserves are largely concentrated in certain regions of the world.

Fossil fuel combustion also results in air pollution, acid rain and build-up of carbon dioxide, thus putting humans, wildlife and the environment at risk.

Among the alternatives to fossil fuels, biofuels such as biogas, alcohols and biodiesels have received considerable attention due to their renewable nature and their inherent potential to bring down net CO_2 emission.

The use of biogas in conventional SI and CI engines has been a topic of extensive research over the past few decades. In CI engines, the inducted bio gas air mixture can be ignited by injecting a small quantity liquid fuel with high cetane number, termed pilot fuel, close to the top dead center (TDC). This is known as the dual fuel mode. Another option is to compress the inducted biogas air mixture till self-ignition occurs. This is called homogeneous charge compression ignition (HCCI) mode. The present work focuses on using biogas in dual fuel mode with diesel as the pilot fuel. The self-ignition of the pilot fuel initiates a flame which traverses the combustion chamber, consuming the biogas air mixture.

A lot of research papers have been published in many journals on this research, so we understand that researcher have worked on this dual fuel system and this method can play a very good role in the future, for power generation in the field of goat farm, cattle farm, poultry or layer farm sector.

2.2. Previous Work:

In new and developing agriculture sector, the research is being carried out day by day. In this field, the most popular research is going on the conversion of diesel engine into dual fuel engine.

Willie Scott Jensen: (2006) has worked on the conversion of the diesel engines into dual fuel engine. In his research, he has come up with a number of pros and cons of conversion. A Dual Fuel diesel engine (traditionally) is a diesel engine that has been fitted with additional devices allowing it to utilize natural gas as a supplemental fuel. This engine type is a true diesel and requires some level of diesel for operation, for ignition of the gas fuel. This engine type has been available to industry since the 1930 the dual fuel engine type has a number of quality attributes. A primary benefit that of fuel flexibility, operating with cleaner and cheaper natural gas. Many hundreds of these engines were operated in USA during the rural electrification period. But after grid depression of 1928 economical many of these engines were discarded.

Semin, Rosli Abu Bakar: (2008) has worked on the compressed natural gas as an alternate fuel for an internal combustion engine. In our research, of his work we found that, how a CNG is used as an alternate fuel with spark ignition engine and compression ignition engine. In this, we found, during the CNG engine development, that CNG could also be efficiently used in a diesel engine Furthermore, the research is still going on to achieve the desired objective of producing a diesel engine capable of operating on CNG fuel thus making the vehicle more eco-friendly and less harmful to the nature.

Abdul Wahab Siyal: (2015) On the basis of results deducted from data analysis it can be concluded that running of diesel engine in dual fuel mode saved almost 62% to 64% diesel fuel, showing an annual saving of Rs. 122010 & 74340/ when run on dual fuel mode with respect to gas produced from fixed dome and floating drum biogas digesters respectively. Running engine through floating type biogas digester consumed 6.35% more diesel than fixed dome biogas digester in dual fuel mode. A 16 hp dual fuel diesel engine pumped 14 % more water from fixed dome biogas plant as compared floating drum biogas plant.

M. Feros khan & Saleel Ismail: (2016) The investigations presented in this study led to following conclusions:

Dual fuel mode enhances the combustion quality and brake thermal efficiency (and hence reduces BSEC) at high loads, especially with small rates of methane/biogas intake. The CO2 content of biogas does not influence brake thermal efficiency significantly.

While volumetric efficiency is not affected by increasing the methane flow rate, activating the CO2 jet caused a reduction. However, all biogas mixtures had nearly equal volumetric efficiency, indicating that it is independent of the methane fraction.

Mateos Kassa and Carrie Hall: (2018) Since the inception of the dual-fuel combustion strategy as a tool to better control combustion, its application has been most vital in stationary and heavy-duty applications. The integration of the dual-fuel combustion in the transportation industry promises great benefits both in terms of fuel efficiency improvement as well as toxic emissions reduction. Significant efforts are undertaken to implement this technology in the automotive industry for heavy-duty, as well as medium and light-duty engines. The on-going research on dual-fuel combustion promises encouraging paths that will allow the utilization of more readily available gaseous fuels and renewable fuels. The observed benefits on both compression-ignition and spark-ignited engines warrants further investments, research, and efforts to better exploit these gains on a larger scale.

While the technology has successfully been used in stationary applications, the implementation of dual-fuel strategy on mobile applications, specifically in the transportation sector, still faces limiting challenges. In addition to the technical challenges associated with the dual-fuel engine, a primary concern for its integration in the automotive industry consists of the social resistance to the requirement of having and filling two fuel tanks. In order for the technology to successfully penetrate the automotive market, the benefit in the terms of fuel efficiency improvement and toxic emissions reduction need to clearly outweigh the technical and social challenges.

In 1981 an effort has been made to use biogas in a converted diesel engine to SI engine by **D. J. Hickson.** He experienced 35% less power compared to diesel and 40% less compared to gasoline fuel. In that year another research was done by **S. Neyeloff and W. W. Cunkel**. They used a CFR engine and ran it with simulated biogas in different compression ratios. They reached to compression ratio of 15:1 for optimal solution.

The lower heating value, corrosive composition and difficulties in transportation of the fuel were main challenges for biogas.

In 1983**, R.H. Thring** concluded that biogas would be attractive just where it is close to production site and he suggested converting gaseous fuels like biogas or natural gas to liquid fuels such as methanol or gasoline.

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2.3: Conclusion:

Due to the increase in the price of the diesel in the current global market, the impact on the poultry farm may not affect the production of meat and eggs. So, we have decided to use the bio gas we get from the chicken droppings as a dual fuel. The powered demand we choose the renewable energy. Our project of bio gas & diesel power dual fuel system is successfully completed and the results obtained are satisfactory. It will be easier for the people who are going to use this project for the further modifications. This project is more suitable for agriculture & farm sector as it is having much more advantages save diesel fuel & cost, pollution, waste reduces.

Chapter-03

FUEL

3.1. Main Fuel of Engine:

Diesel: Diesel fuel is the common term for the distillate fuel oil sold for use in motor vehicles that use the compression ignition engine named for its inventor, German engineer Rudolf Diesel. He patented his original design in 1892. Diesel fuel is refined from crude oil and from biomass materials.

Density & Viscosity of Diesel: The density of petroleum diesel is about 0.85 kg/l – about 15–20% higher than the density of gasoline, which has a density of approximately 0.70–0.75 kg/l.

Table 1

Density & viscosity of diesel:

No.	Diesel Fuel		RME		Temperature	Density	Dynamic Viscosity
	mL	%	mL	%	°C	$g \cdot cm^{-3}$	mPa·s
1	1,000	100%	0	0%	40	0.785	1.352
2	947	95%	53	5%	40	0.788	1.412
3	842	84%	158	16%	40	0.793	1.459
4	737	74%	263	26%	40	0.799	1.487
5	632	63%	368	37%	40	0.804	1.534
6	526	53%	474	47%	40	0.810	1.617
7	421	42%	579	58%	40	0.814	1.643
8	316	32%	684	68%	40	0.819	1.709
9	210	21%	790	79%	40	0.825	1.751
10	0	0%	1,000	100%	40	0.835	1.881

Table 2

Properties of diesel;

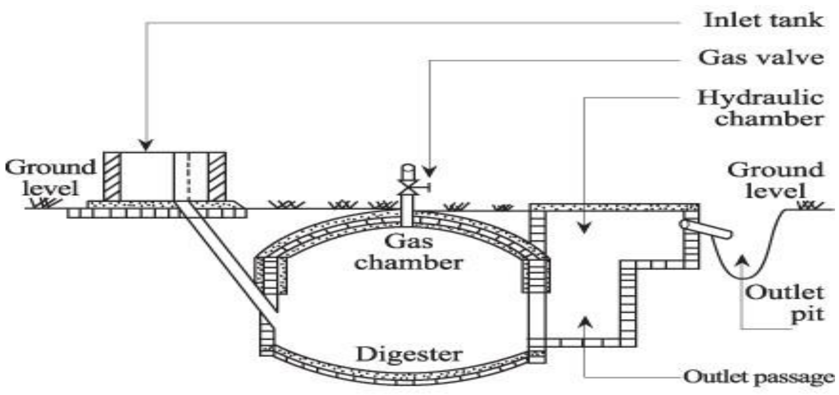
Properties	Value	Test method adopted
Kinematic viscosity at 40*c	2.58	ASTM D 445
Fire point, *c	56	ASTM D 93
Specific gravity value at 15 *c	0.83	ASTM D 4052
Lower heating value, MJ/kg	43.8	ASTM D 4809
Cetane number	50	ASTM D 613
Flash point, *c	50	ASTM D 93

3.2. Experimental Primary Fuel of Engine:

Bio Gas: Biogas is a mixture of gases, primarily consisting of methane, carbon dioxide and hydrogen, produced from raw materials such as agricultural waste, manure, municipal waste, plant material, sewage, farm waste, green waste and food waste. It is a renewable energy source.

Processing bio gas:

After making a bio gas plant, given regular amount of chicken droppings and water every day. By processing this chicken droppings in the digester, bio gas accumulate in this gas chamber and organic fertilizer will come out with the output of the plant.



Fixed dome type biogas disgester

Table-3 Bio gas properties:

Composition	Processed biogas	Raw biogas
Methane (CH_4)	97.3 %	55.7 %
Carbon dioxide (CO_2)	1.6 %	44.1 %
Nitrogen (NO_2)	0.7 %	NA
Oxygen (O_2)	0.4 %	0.1 %
Hydrogen sulfide (H_2S)	0 ppm	5 ppm

Fig.3.2: Layer farm in BD

-

Fig.3.3: Layer farm lighting.

Fig.3.4: Bio gas plant

Fig.3.5: Bio gas waste input drain.

CHAPTER-04

METHODOLOGY

4.1. Introduction:

Engines that can operate using a mixture of two different fuels are called dual fuel engines. Frequently, diesel and natural gas fuels are used together within dual fuel engines.

Beyond natural gas and diesel, some dual fuel engines can also use varying mixtures of biodiesel, landfill gas, bio-gas and other fuels.

Dual-fuel engine is the diesel engine that can run on both gaseous and liquid fuels. When running in gas mode, the engine works according to the Otto process where the lean air fuel mixture is fed to cylinders during the suction stroke. Efficiencies exceeding 47% have been routinely recorded. When running in diesel mode, the engine works according to the Diesel process where the diesel fuel is fed to cylinders at the end of compression stroke. The engine is optimized for running on gaseous fuels and diesel fuel is used for back-up fuel operation.

Wartsila began development work with dual-fuel gas engines in 1987, the first concept being the gas-diesel (GD) engine with high-pressure gas injection. This was followed by the second generation of gas engines in the early 1990s, when the company introduced spark-ignited (SG) pure gas engines using low pressure gas. The real breakthrough, however, came when the dual-fuel (DF) engine was introduced by Wartsila in 1995. This resulted in the ability to combine fuel flexibility and efficiency with environmental performance.

4.2: Necessary Equipment:

Fig.4.1: Changzhou Diesel engine 8 hp

Fig.4.2: Electric Generator 5 kw.

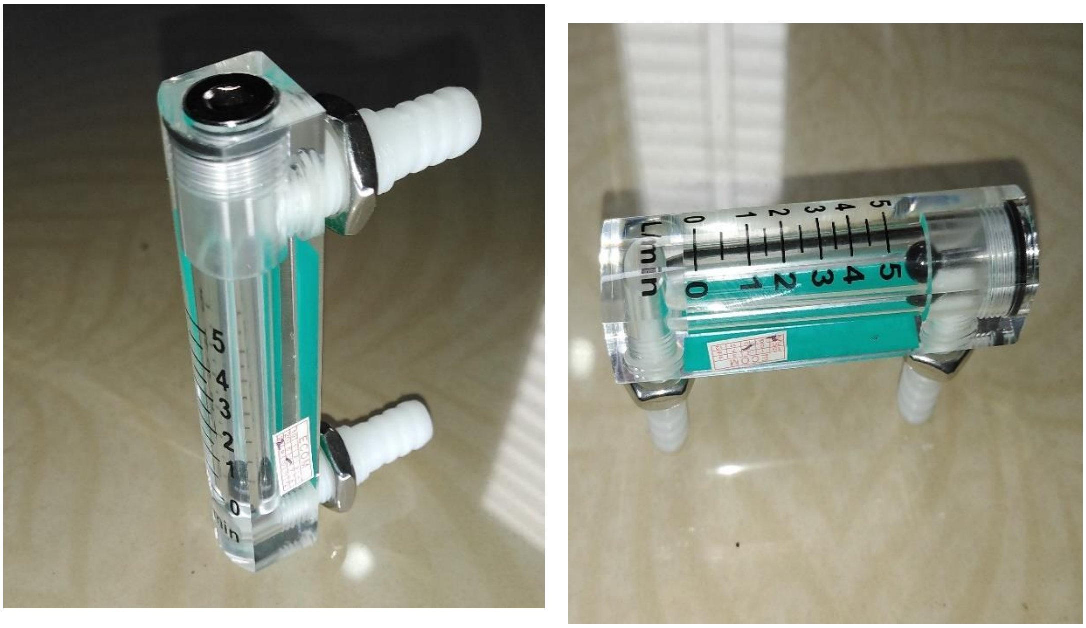


Fig.4.3: Flow Meter

Fig.4.4: Temp. + Humidity meter

Fig.4.5: Gas cylinder

Fig.4.6: Gas Pipe

Fig.4.7: Pressure gauge

Fig.4.8: Gas control valve

Fig.4.9: Volt meter.

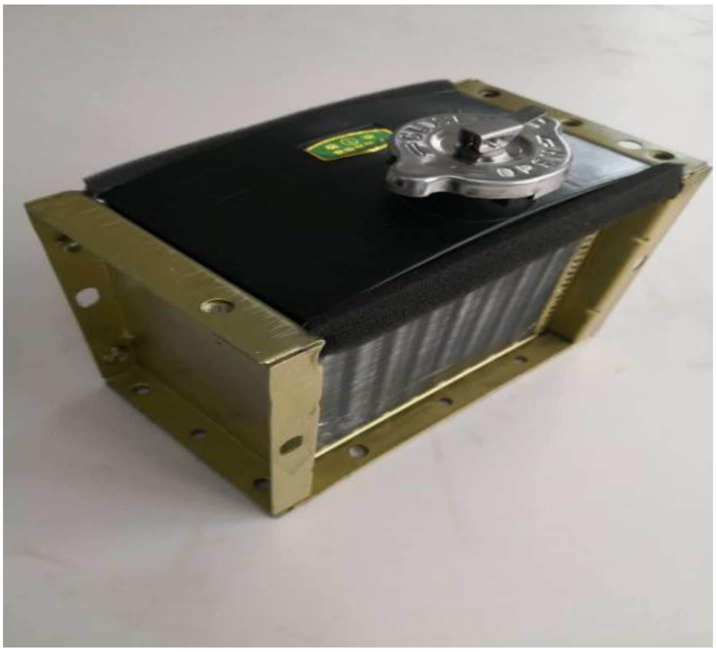


Fig.4.10: Radiator cooling system

4.3. Setup Description:

Fig.4.11: Dual fuel Setup Project picture.

Fig.4.12: Dual fuel Setup Project picture 2

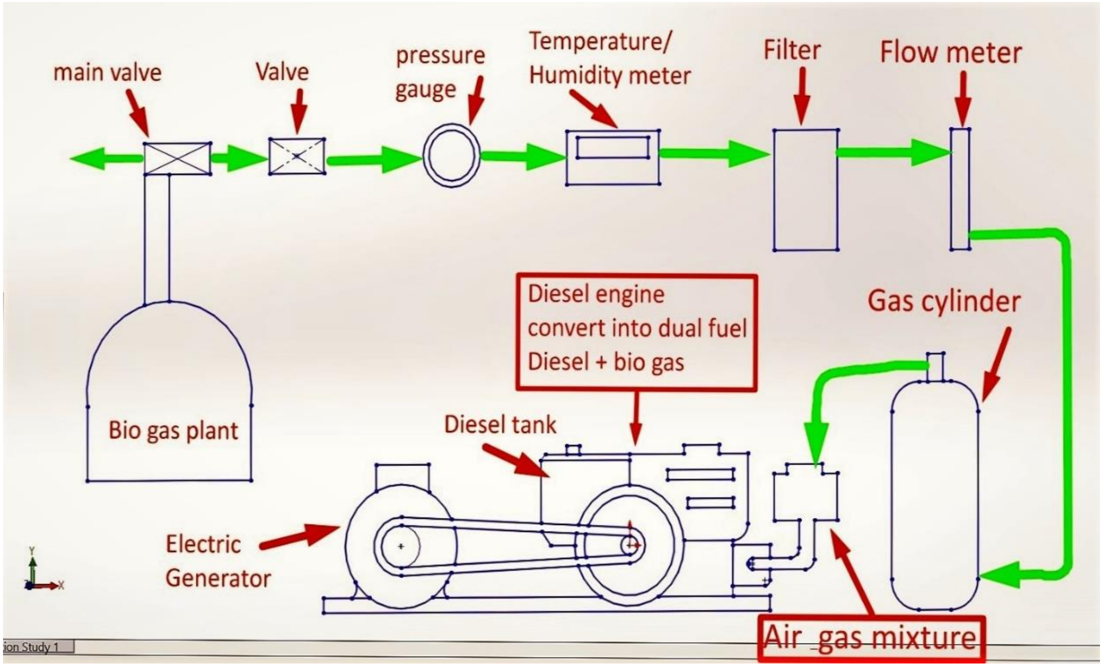


Fig4.13: dual fuel setup drawing.

Through this diagram we can understand that the gas is connected to the engine through the pipe line from the bio gas plant. The main valve is connected to the control valve through a pipe. The bio gas is filtered from the control valve with a pressure gauge and humidity meter. The filtered bio gas enters the gas cylinder measured by the flow meter. The gas from the cylinder passed through the venturi pipe to the compression chamber in the inlet manifold of the engine.

4.4: Working principle:

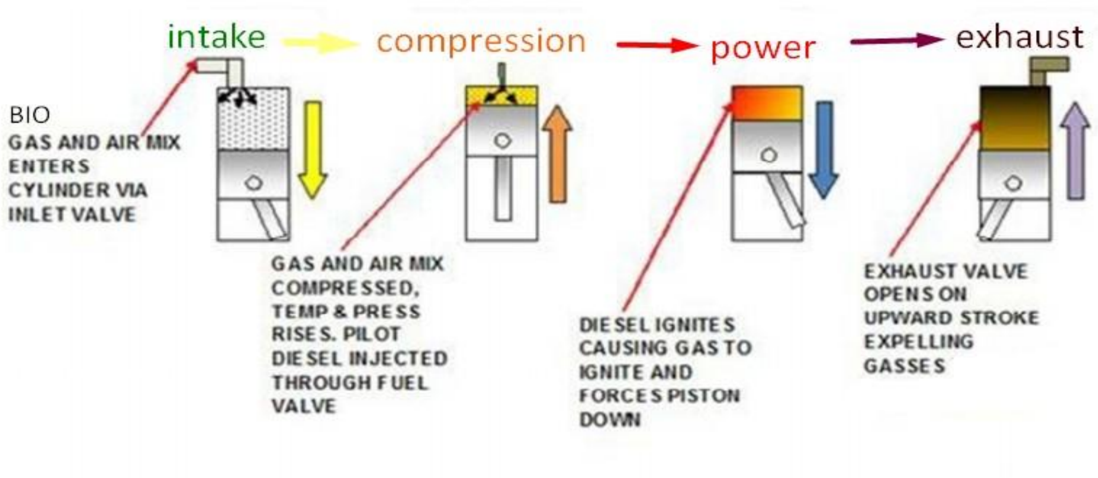


Fig.4.14: Bio gas/ Diesel dual fuel 4 stroke engine operation

1. Intake Stroke:

As the piston descends into the cylinder, a measured amount of gas in injected into the air inlet manifold and is sucked into the cylinder as a gas/air mixture.

2. Compression Stroke:

The piston continues down until it reaches BDC; it then rises back up the cylinder, compressing the air/gas and increasing its temperature. Before the TDC, a measured quantity of diesel oil (pilot diesel) is injected into the combustion chamber.

3. Power Stroke:

The small amount of diesel ignites into hundreds of little sparks due to compression combustion. This in turn sets off the combustion of bio gas that powers the piston back down the cylinder.

4. Exhaust Stroke:

The piston returns to BDC and, as it begins to rise up the cylinder, the exhaust valve opens expelling the exhaust gasses into the turbo-charged inlet turbine, thus completing the 4-stroke cycle.

The research engine used in this operation was a Chinese 8 hp diesel engine, model R180. It is one of the most popular engine models in Bangladesh. The engine is of the 508 cm^3, single cylinder, Horizontal type with overhead poppet values, and has a bore of 80 mm and a stroke of 80 mm. The combustion chamber is cylindrical in shape with the compression ratio of 18:1. The four-stroke, water-cooled, compression ignition engine is nominally rated at 5.5 kW at 2400 r/min and develops 23.4 Nm of torque at 2025 r/min. The engine, shown schematically in (fig.4.1), is coupled to a 5.0 kW, 220 V, single phase, AC, 50 Hz alternator acting as a generator to allow for accurate manual speed and load control. (fig.4.2)

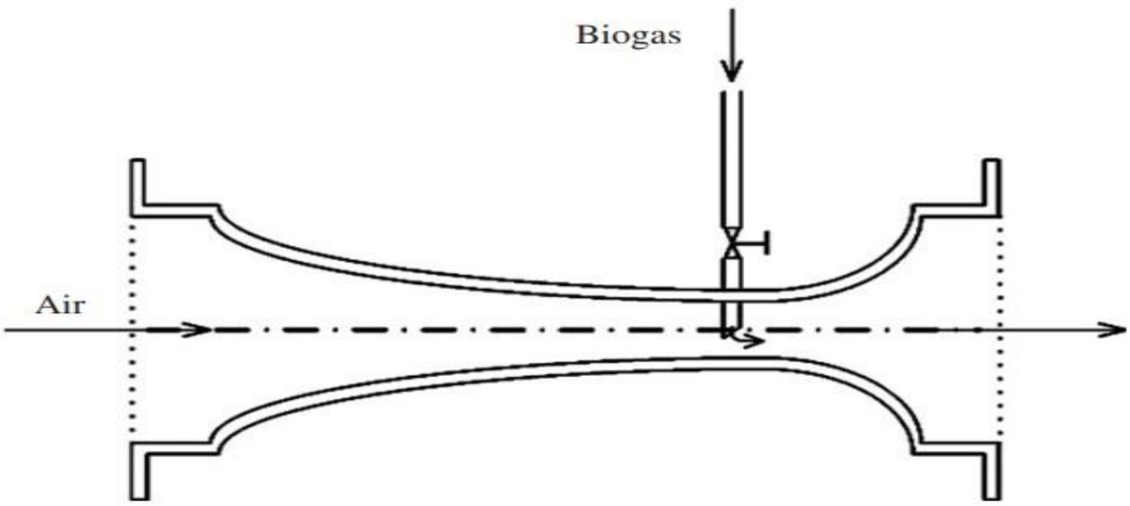


Fig.4.15: Venturi type mixer

Biogas was supplied through a plastic pipe and mixed with inlet air in a venturi-type mixer (Fig.4.15) upstream of the inlet manifold. The inlet air duct was kept wholly open with no throttle or any flow obstruction. Diesel consumption rate was measured via timing a fixed amount of diesel fuel used in a calibrated burette. Engine speed was measured by generator volt meter. The air and biogas flow rates were regulated using a flow meter and a biogas meter respectively. Thermocouples connected & measure inlet air and exhaust temperatures, the cylinder wall as well as coolant temperatures. Initially, the engine was conditioned by running at idle for 2 h on diesel fuel. Subsequently, the test procedure began with normal operation at idle for about 15min. The engine speed was then increased gradually to 1400 r/min. Once stability was attained, a constant speed testing was carried out with a load applied. The data acquisition was then undertaken. The tests were conducted at a number of constant speeds (1400–2000 rpm) under both diesel and dual-fuel. Several readings were taken and the average value was computed. Under biogas/diesel dual-fuel operation, an effort has been made to keep the pilot amount of diesel fuel constant, while the engine power output was adjusted through the amount of biogas.

The power or hp depends on the mean effective pressure of cylinder volume of the engine. When mean effective pressure or power increased then BHP, RPM & Thermal efficiency increased. Then engine governing system control the engine fuel throttle valve. Increasing RPM reduce diesel fuel consumption and decreasing RPM increasing diesel flow on the engine. Bio gas flow on the intake system Mean Effective Pressure is increased so governor less the diesel flow rate. A mechanical governor uses flyweights to create a force based off of crankshaft speed which is balanced by the force of the governor spring. The top engine speed is varied by increasing the spring force to run faster or decreasing the force to run slower

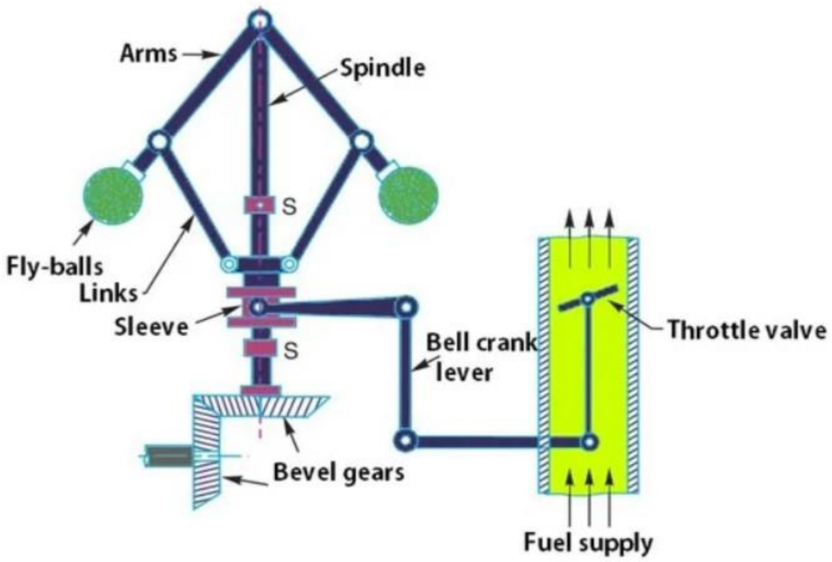


Fig.4.16: Diesel Engine Governor.

Nomenclature

- H_{biogas} heating value of biogas, $kJ\,kg^{-1}$
- H_{diesel} heating value of diesel, $kJ\,kg^{-1}$
- $\dot{m}_{biogas}$ biogas consumption rate, $kg\,s^{-1}$
- $\dot{m}_{diesel}$ diesel consumption rate in normal diesel operation, $kg\,s^{-1}$
- $\dot{m}_{dual}$ diesel consumption rate in dual-fuel operation, $kg\,s^{-1}$
- r diesel replacement by biogas, %
- f_s specific fuel consumption, $g\,kW^{-1}h^{-1}$
- W power output, kW
- η thermal efficiency, %

To present the percentage of diesel replacement by biogas r, the following expression is adopted:

$$r = \frac{\dot{m}_{diesel} - \dot{m}_{dual}}{\dot{m}_{diesel}} \times 100. \quad (1)$$

The total specific fuel consumption f_s and thermal efficiency η are calculated according to

$$\left.\begin{array}{ll} f_s = \frac{\dot{m}_{diesel}}{W} & \text{for normal diesel operation,} \\ f_s = \frac{\dot{m}_{dual} + \dot{m}_{biogas}}{W} & \text{for dual-fuel operation,} \end{array}\right\} \quad (2)$$

$$\left.\begin{array}{ll} \eta = \frac{W}{\dot{m}_{diesel} H_{diesel}} & \text{for normal diesel operation,} \\ \eta = \frac{W}{\dot{m}_{dual} H_{diesel} + \dot{m}_{biogas} H_{biogas}} & \text{for dual-fuel operation,} \end{array}\right\} \quad (3)$$

where **m** $_{diesel}$ is diesel consumption rate in normal diesel operation, **m** $_{dual}$ is diesel consumption rate in dual-fuel operation and **m** $_{biogas}$ is biogas consumption rate in kgs^{-1}; W is the engine power output in kW and H is the fuel heating value in kJ kg^{-1}.

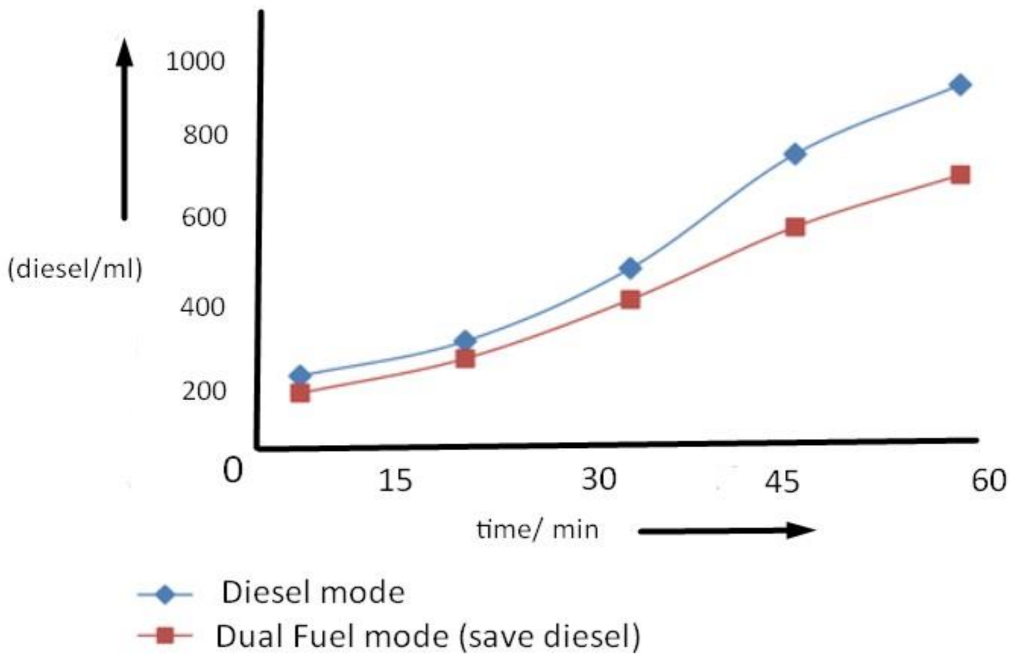


Fig.4.17: Fuel consumption curve

For engine operation, the engine was directly coupled to the same alternator. It was set to run on dual-fuel operation at a constant engine speed of 2000 rpm to generate electricity continuously. The electricity produced used for fan's, light's & pumping water in the farm. The engine was run for an average per day about 6 hours durability test in 3 months. Engine check and services were performed after 540 hours. All critical components were taken apart, weighed, inspected and photographically recorded (fig.4.19 & fig.4.20).

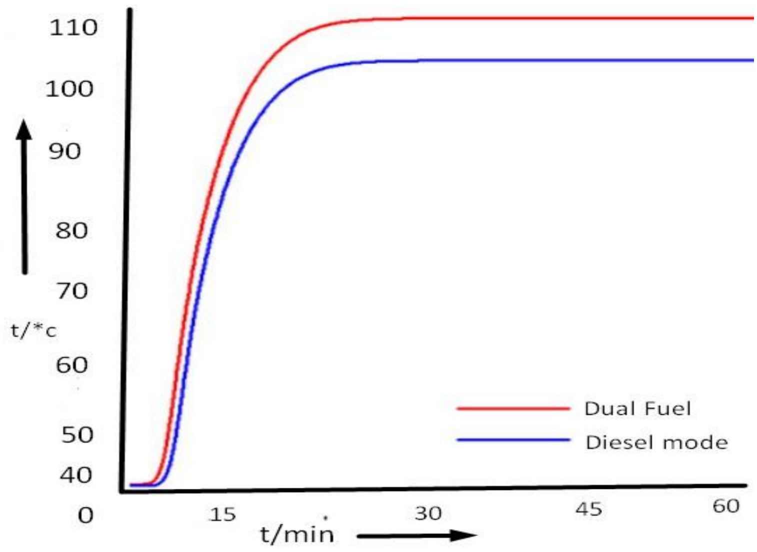


Fig.4.18: Engine temperature.

Biogas with 90% methane gives the highest exhaust temperature among all diesel biogas dual fuel runs there no clear relationship is observed between methane content and exhaust temperature for the other cases. This is possibly because CO_2 has two conflicting effects on biogas combustion: it tends to reduce the temperature by dilution effect, while it also extends the duration of combustion and hence the temperature of expelled gases & buildup carbon.

Fig.4.19: Carbon buildup on engine valve.

Fig.4.20: Carbon buildup on head.

Carbon deposits can disrupt airflow, causing the engine to operate outside of OEM spec. This results in operational turbulence that makes the air-fuel ratio inconsistent. This inconsistency causes the engine to experience rich and lean mixtures, which have an adverse effect on the long-term reliability of the engine and cause hotspots within the combustion chamber of the engine. Hotspots dramatically affect engine efficiencies. Areas, where carbon buildup has localized, will likely experience overheating, due to carbon's nature of "holding" heat. This can lead to engine knock and a drastic reduction in engine efficiency.

The engine was later cleaned and reassembled in strict accordance with all furnished specifications.

Fig.4.21: Clean engine valve Fig.4.22: Clean engine head

4.5. Install extra cooling system:

As the diesel engine is converted to dual fuel, the temperature of this engine is slightly higher than the diesel mode, so adding an extra cooling system will keep the engine temperature controlled. This will increase the life of the engine and prevent the formation of carbon deposits. This system cool intake air and gas mixer then cool engine oil then engine jacket water. It is very effective system for dual fuel engine.

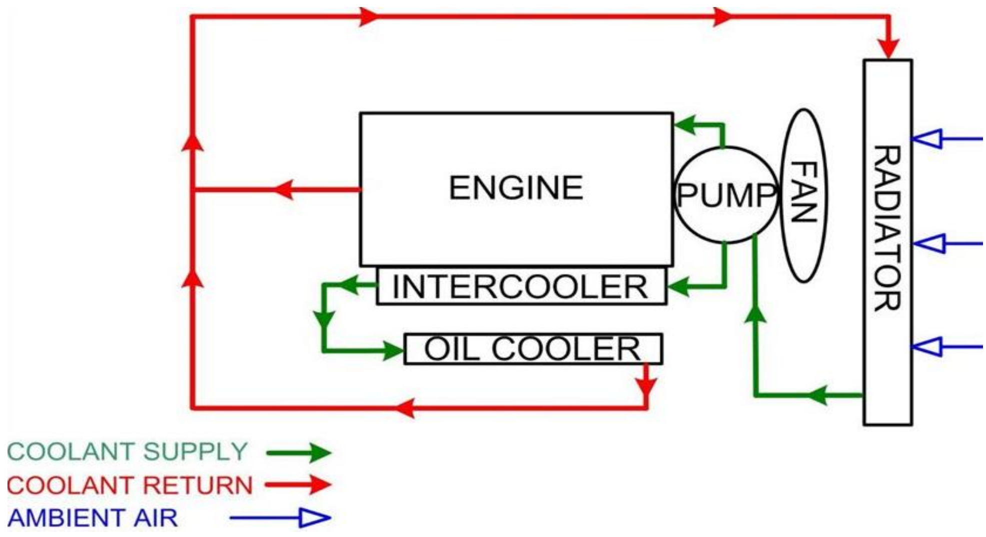


Fig.4.23: Cooling system

4.6. Conclusion:

In this study, a single cylinder, four stroke water cooled diesel engine was converted into a dual fuel system operated. Bio gas contain very small amounts of sulfur dioxide. It is toxic gas. The sulfur dioxide in the bio gas reacts, slightly raising the engine temperature and forming a layer of carbon. So steps should be taken to reduce engine temperature. Adding an extra cooling system will keep the engine temperature controlled. It is very effective system for dual fuel engine.

Chapter-05

RESULT ANALYSIS

5.1. Introduction:

The study concludes the biogas production from organic wastes, for use in I.C engines. Different techniques for CO_2, H_2S scrubbing are discussed, among which water scrubbing is a simple continuous and cost effective method for purification. Attention is also focused for making biogas as alternate fuel in Diesel Engines and dual fueling is recommended to be the best one for biogas CI operation. Drop of CO_2 in biogas for dual fueling increases the thermal efficiency. In biogas dual mode, the presence of CO_2 controls the high heat release rate; hence the durability of engine components will not be affected. Therefore it is recommended to use biogas as alternate fuel in diesel engines.

5.2. Results & Discussion:

Methane is the main component, leading to a relatively high number, which makes it suitable for high compression ratio engines. Nonetheless, a relatively high concentration of sulfur compound is noticeable. It is highly toxic and responsible for the formation of sulfur dioxide during combustion, which is responsible for engine corrosion. From observation, there was a marginal variation among major gas constituents during the experimental campaign. No significant temporal variation of gas concentrations was observed in any day. The reactor appeared to be air tight and no dilution with ambient air was reported. May likely be the inability of the engine to induce biogas sufficiently into the combustion cylinder for engine power production at higher speed. Supplied static pressure of biogas was only about 100-150 Pa. At this low biogas pressure and suction created from intake stroke of the small engine. At higher speed, volumetric efficiency of the engine may be adversely affected by the presence of a greater amount of biogas. Adequate air for complete combustion may not consequently be induced into the engine cylinder, leading to higher emissions.

They were, on average, about 550 and 450 g kW1h1 for dual-fuel and normal diesel operations, respectively. Dual-fuel operation proved to have higher efficiency than that under normal diesel operation. Maximum thermal efficiency of approximately 23% may be expected at 1500 rpm for electricity generation.

However, the specific fuel consumption and efficiency decrease significantly as biogas flow rate increases. On the other hand, emission of the engine on dual-fuel mode is better. The main conclusion can be drawn is that engine without significant modification can be operated perfectly in dual-fuel mode and diesel oil consumption can be decreased up to 40.5%.

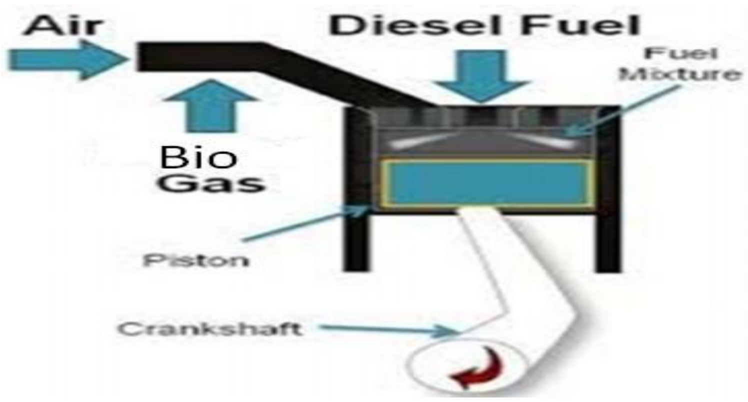


Fig.5.1. Burn dual fuel

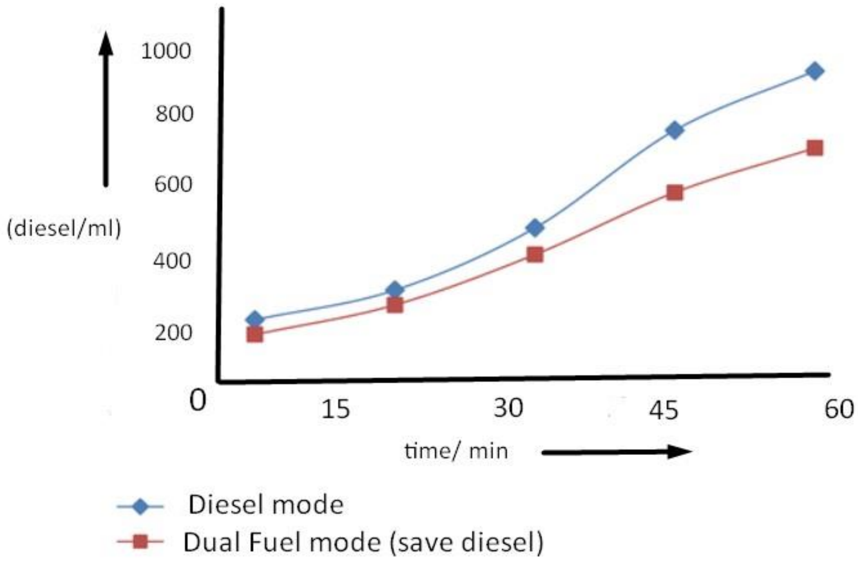


Fig.5.2. Avg.40% Save diesel curve

Table-4

Diesel mode:

DAY	HOURS	LOAD	FUEL CONSUMPTION
1st	6	4300 w	6L
2nd	2	4000 w	2L
3rd	5	3000 w	4.8L
4th	4	3800 w	4L
5th	3	2000 w	2.6L
6th	5	4200 w	5L
7th	4	1500 w	4.5L
8th	6	2000 w	5.6L
9th	4	3500 w	3.9L
10th	7	2900 w	6.8L

Here,

Days = 10

Hours = 46 h

Avg. hours per day = 4.6 h

Loads = 31200 w or 31.2 kw

Fuel consumption = 45.2 L

per hour fuel consumption = 1 L

Table-5

Dual Fuel Mode:

DAY	HOURS	LOADS	FUEL CONSUMPTION
1st	5	3800 w	3L
2nd	7	4300 w	4.2L
3rd	3	2700 w	1.8L
4th	6	4500 w	3.6L
5th	5	2000 w	3L
6th	3	1500 w	1.6L
7th	5	2600 w	3.2L
8th	4	3400 w	2.4L
9th	6	3000 w	3.6L
10th	4	4000 w	2.4L

CHAPTER-06

Conclusion

6.1. Conclusion:

Owners or operators of existing diesel engines interested in cost savings should evaluate the benefits of a dual-fuel conversion. While the dual-fuel engine concept is not new, rising diesel fuel costs, more emphasis on emission regulations, desire to increase engine maintenance intervals, and controlling overall costs of operation are increasing interest in this technology.

Offering ease of installation and relatively low capital investment, dual-fuel conversions provide the ability to realize this cost savings and adhere to regulations through the use of bio gas

fuel in both low- and high-speed industrial engine applications.

Since the inception of the dual-fuel combustion strategy as a tool to better control combustion, its application has been most vital in stationary and heavy-duty applications. The integration of the dual-fuel combustion in the transportation industry promises great benefits both in terms of fuel efficiency improvement as well as toxic emissions reduction. Significant efforts are undertaken to implement this technology in the automotive industry for heavy-duty, as well as medium and light-duty engines. The on-going research on dual-fuel combustion promises encouraging paths that will allow the utilization of more readily available bio gas fuels and renewable fuels. The observed benefits on both compression-ignition and spark-ignited engines warrants further investments, research, and efforts to better exploit these gains on a larger scale.

6.2. Limitation:

There are several notable limitations in the report:

→ Dual fuel diesel engine system is very critical topic so we needed to study a lot more about it.

→ Due to constraints of time, the sample size is limited.

→ As the questionnaire was condensed; certain factors could not studied in depth.

→Most of the information provided in the project report is collected from different projects.

→The time allotted for projects was 12 months.

→The cost of some instruments and tests are considered too expensive, so could not use them.

→ All these sites require a lot of money to operate which we have not able to mobilize.

6.3. Future Recommendation:

6.3.1. Purification of Biogas for I.C. Engine:

Removal of CO_2

CO_2 is high corrosive when wet and it has no combustion value so its removal is must to improve the biogas quality. The processes to remove CO_2 are as follows

a) Caustic solution, NAOH- 40% NAOH + CO_2 = $NAHCO_3$

b) Refined process, K_2CO_3 - 30 % $K_2CO_3 + CO_2 = 2KCO_3$

CO_2 removal from biogas can be done by using chemical solvents like mono-ethanolamine (MEA), di-ethanolamine and tri- ethanolamine or aqueous solution of alkaline salts, i.e. sodium, calcium hydroxide and potassium. Biogas bubbled through 10% aqueous solution of MEA can reduce the CO_2 content from 40 to 0.5-1.0% by volume. Chemical agents like NaOH, Ca $(OH)_2$, and KOH can be used for CO_2 scrubbing from biogas. In alkaline solution the CO_2 absorption is assisted by agitation. NaOH solution having a rapid CO_2 absorption of 2.5-3.0% and the rate of absorption is affected by the concentration of solution

Removal of H_2S

In physical separation pressurized water is used as absorbent, as both CO_2 and H_2S are water soluble agents. The water scrubbing method is used for biogas up gradation. The rate of CO_2 and H_2S absorption depends upon the factors such as, gas flow pressure, composition of biogas, water flow rates, and purity of water and dimension of scrubbing tower. A purity of 100% CH_4 can be obtained by a pressurized water scrubbing tower with counter current. A reduction of CO_2 from 30% to 2% in biogas is achieved, when the gas flow rate was 1.8m^3/h at 0.48 bar pressure and water flow rate was of 0.465m^3/h in a continuous counter current type scrubber. Compressed biogas at 5.88 bar pressure while passed through a 6 m high scrubbing tower at a flow rate of 2m^3/h gives 87.6% removal of CO_2. Solid membrane of acetate-cellulose polymer has permeability for CO_2 and H_2S is 20 to 60 times greater than CH_4, when the biogas flow pressure is maintained at 25-40 bar. Generally the membrane permeability is <1 mm. For higher methane purity the permeability must be high. Monsanto and acetate cellulose membranes give best separation to CO_2, O_2 and H_2S than CH_4 when temperature and pressure was maintained at 25*c and 5.50 bar respectively. Naturally occurred solid Zeolite- Neopoliton Yellow Tuff (NYT) can absorb 0.4 kg of CO_2 per kg of chabazite at 1.50 bar and 22°C. During this adsorption process H_2S content is removed out.

6.3.2. Maintain Overhaul Schedule:

Engine overhauling should be done according to engine overhauling time. An overhaul always includes a complete disassembly of the engine, thorough cleaning and inspection of parts, repair of parts as needed and disposal of defective parts. Major items such as the crankshaft, crankcase and connecting rods are subject to special inspections. It is very important for dual fuel diesel engine.

6.3.3. Bio gas plant Maintenance:

To prevent possible accidents, the project developer can, among other things:

- ➔ Install the equipment with ladders or pits with protective panels or grilles
- ➔ Clearly identify moving parts
- ➔ Install signage in hazardous areas.

CHAPTER-07

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