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Research Article

A Research Paper on Performance and Emission Analysis of CI Engine for 100% POBD with Different Proportions of Biogas

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Abstract

These research works mainly focus on the utilization of biomass, for this one experimental setup is geared up it is basically single cylinder four stroke diesel engine that was modified to run in dual fuel mode of neat POBD ***(Palm oil biodiesel)*** *and different proportions of biogas. By using these biofuels (Biodiesel & Biogas), various performance and emission parameter were obtained like FC, BSFC, BTE, CO_2, HC, CO etc. The values obtained of such parameters are comparable with traditional diesel that was also obtained from same setup. This results show under dual fuel mode i.e.* ***(BD+BG) biodiesel-biogas mixture*** *at low load condition, BG (2 gm/min) added in neat BD, BSFC of biodiesel reduces to 7.14% and when BG (8 gm/min) added in BD, BSFC of biodiesel reduces up to 14.268%. Also CO_2 emission of biodiesel is reduces to 0.63% at low load condition and 0.77% at high load condition. An overall evaluation of the results indicates that the biogas and biodiesel in dual fuel operation could be substituted in place of diesel fuel in power generation, where there is unavailability of the traditional (fossil) fuels.*

Keywords: *palm oil, duel fuel mode, FC, BTE, BSFC, POBD*

1. Introduction

In world year by year man's dependency on energy has increased rapidly mainly because of the increase in population, the living standards like use of various type of energy, vehicles and use of advance technologies in the industry and transportation field. Today the main source of energy is fossils fuels like-coal, petroleum, natural gas, uranium etc. Since these sources of energy limited in nature will last in few years, hence their proper utilization is the main concern these days therefore it mainly requires the basic understanding for their proper utilization and conservation for their future use. "Any source of thermal energy or heat energy is known as fuel". Coal is a much dirtier source of fuel than oil or natural gas. Burning coal creates environmental problems for the immediate area surrounding a coal fired plant. Acid rain and acid lakes are also link to coal fired power plants. Damage to the environment raises questions of energy costs .In assessing the location of energy reserves and consumption, now time has to examine the environmental and financial costs of particular types of energy.Climate negotiators work towards a deal that would limit the increase in global temperature, so interest is growing in the essential role of technology innovation can and must play in enabling the transition to a low-carbon energy system. For example like biomass energy, solar energy, wind energy and biogas Mentioned sources of energy are all renewable, but biogas is particularly significant because of possibility of use in internal combustion engines, which are the main power source for transport vehicles and also commonly used for powering of generators of electrical energy. (TERI, 2010) This possibility of use is justified by biogas properties, which make it convenient for IC engines. India is largest cattle breeding country; there is abundance of raw material for producing biogas. Also municipal wastes & kitchen wastes can be used for this purpose.

The use of methane (CH_4) separated from biogas as a fuel will substantially reduce harmful engine emission and will help to keep the environment clean. Biogas consists of approximately 50-70 % methane. It is economical and slurry can be used as organic manure. (geni.org) Biogas is produced by extracting chemical energy from organic materials in a sealed container called a digester. The generation of biogas is the concept of anaerobic digestion, also called biological gasification. It is a naturally occurring, microbial process that converts organic matter to methane and carbon dioxide. The chemical reaction takes place in the presence of methanogenic bacteria with water an essential medium. The anaerobic digestion process, a biogas plant should be no oxygen within the digester. Energy is one of the major inputs for the economic development of any country. In the case of the developing countries, the energy sector

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assumes a critical importance in view of the ever increasing energy needs requiring huge investments to meet them. (TERI, 2010) Energy can be classified into several types. It is primary and secondary, commercial and non commercial, renewable and non renewable energy.

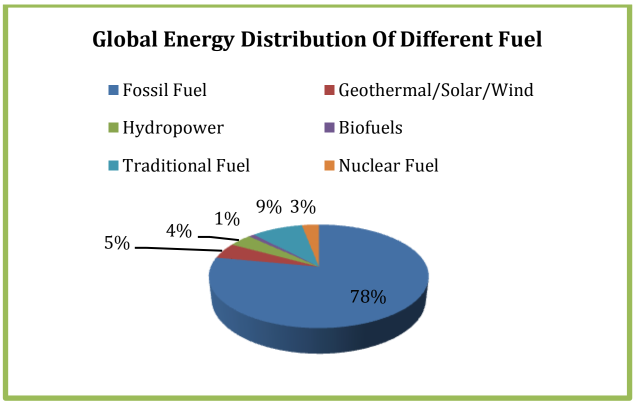

Figure1.1 Global Energy Share of Different Fuel (A.Aziz and M.F. Said, 2005)

Primary energy sources are those that are either found or stored in nature. Common primary energy sources are coal, oil, natural gas, and biomass (such as wood). Primary energy can also be used directly. Some energy sources have non-energy uses; for example coal or natural gas can be used as a feedstock in fertilize plant. (TERI, 2010) The demand for energy has grown at an average of 3.6% per annum over the past few years. This rapid increase in use of energy has created problems of demand & supply. In all over world distribution of various fuel energy are given below in form of pie chart in fig 1.1

Biomass

Biomass inorganic matter derived from living or recently living organisms. Biomass can be used as a source of energy and it most often refers to plants or plant based materials which are not used for food or feed, and are specifically called lignocelluloses biomass. As an energy source, biomass can either be used directly via combustion to produce heat, or indirectly after converting it to various forms of biofuel. Biomass comprises mainly trees and plant wastes (e.g. wood, saw dust, leaves, twigs), agricultural residues, animal and human waste, coal etc. These wastes of plant, animal and human origin are the resources that yield valuable energy and fertilizer. Bio-residues (dung from animal, different types of crop residues such as rice straw, wheat straw, maize stalk, leguminous plant and weeds, aquatic plants) are already widely used in some countries. One of the best options would be to treat the biodegradable wastes into an anaerobic digester in view of producing environmentally sound energy as well as bio fertilizer. Fuel woods resources which represent 78 percent of energy consumption. (Wikipedia).

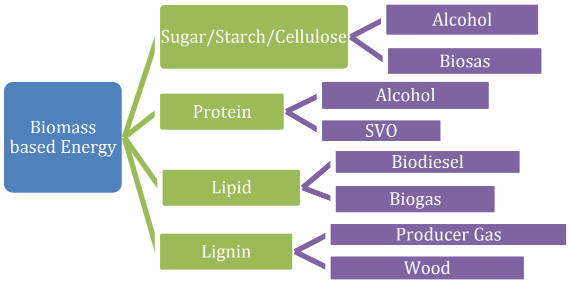

Figure 1.2 Options for biomass based energy

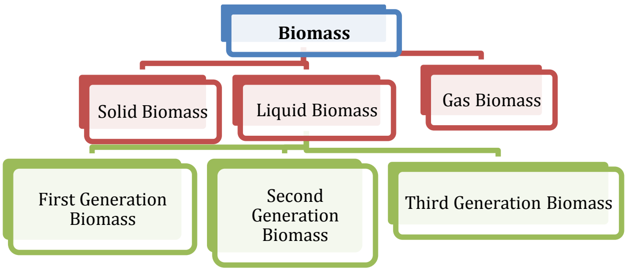

Figure1.3 Classification of Biomass

Biomass conversion techniques are mainly 4 types. The development of conversion technologies for the utilization of biomass resources forth level of technology is beyond their manpower as well as their manufacturing and technological capability. Added to this is the unavailability of local materials and parts for the fabrication of these conversion units. Biomass resources need to be converted into chemical, electrical or mechanical energy in order to have widespread use. These take the form of solid fuel like charcoal, liquid fuel like ethanol or gaseous fuel like methane. In general, conversion technologies for biomass utilization may either be based on bio-chemical or thermo-chemical conversion processes.

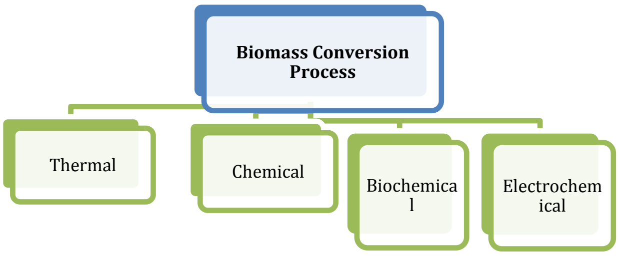

Figure1.4 Biomass Conversion processes

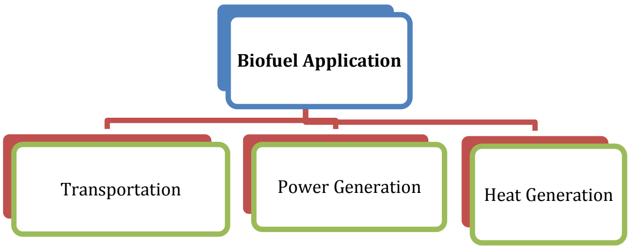

Figure 1.5 Biofuel Major Applications

Table1.1: Physical-chemical properties of palm biodiesel and petroleum diesel

Characteristics	Palm biodiesel (palm methyl ester	Petroleum Diesel
Type of source	Renewable	Fossil
Calorific value (MJ/kg)	41.3	46.8
heat of combustion (KJ/kg)	40.135	45.8
Cetane level	65	53
Flash point (°C)	174	98
Pour point (°C)	16	15
Cloud point (°C)	16	18
Density at 40 °C (kg/L)	0.855	0.823
Viscosity at 40 °C (cST)	4.5	4
Sulphur content (wt. %)	0.04	0.10
Carbon residue (wt. %)	0.02	0.14

1.3 Palm Oil

Palm oil, an oleaginous tropical plant, has the highest oil productivity per unit of land on earth. In terms of its usage, palm oil has various uses as a food, (oils, margarines, bread, mayonnaise, feeds, ice cream, cookies etc), in industry (soap, lubricants, detergents, plastics, cosmetics, rubber etc), in steel making, the textile industry, pharmacology etc (A.R.C.De and L.M.Duarte et al,2007). Among other crops for producing fuel, palm oil demonstrates good competitiveness. Neat palm oil and palm oil blended diesel has emerged as an alternative fuel for an internal combustion (KJ/kg)combustion engine satisfying certain criteria, such as requiring minimum engine modification, offering uncompromised engine life and not being hazardous to human health and the environment during production, transportation, storage and utilization(Wikipedia). Direct use of crude palm oil has been shown feasible in the Elsbett engine. However, a problem of clogging of the filter by impurities is observed, which can be eliminated by using processed liquid palm oil (PLPO) directly or in blends with petroleum diesel to overcome this problem (A.Aziz et al, 2005 and A.R.C.de et al,2007). The increasing demand for vegetable oils is a worldwide phenomenon and palm oil (PO) contributes significantly to the global supply of edible oils. PO is entirely GMO-free and produces up to 10 times more oil per unit area than other oilseed crops. The palm tree (Elais guineensis) is an ancient tropical plant native to many West African countries.

Where local population traditionally use palm oil for cooking and other purpose. Large scale palm crops are found across the tropical regions, and Malaysia and Indonesia are the leading producers of PO, accounting for the 86% of global production; other PO producing countries are Nigeria, Thailand, Colombia, Papa Guinea, India and Brazil.

2. Literature Review

According to Jawad Nagi , ICCBT 2008 - F - (07) – pp79-94 (10)

The results obtained from the survey reveal that palm biodiesel meets the combustion requirements of diesel engine combustion; however, it produces marginally low output characteristics compared to petroleum diesel. The case-study from the survey reveals that palm biodiesel has a number of advantages over petroleum diesel, namely: low fuel consumption, less concentration of exhaust gas emission, higher combustion pressure and longer combustion period. However, contrary to its advantages, palm biodiesel gives marginally low performance in terms of torque, thermal efficiency, and produces higher NOx emissions as compared to petroleum diesel. In the view of majority positive results obtained from the experiments, it is rational to say that palm biodiesel can be used as a substitute for petroleum diesel in diesel engines. Hence, palm biodiesel contributes to be an alternative source of green renewable energy to meet the energy demands of the future.

According to A. Rahmadi and Lu Aye/.Destination Renewables - ANZSES 2003(11)

Developing biodiesel from palm oil for Indonesia would be appropriate as an alternative fuel stock. In the long term, since Indonesia is projected to be the largest CPO exporting country in the next ten years, having an alternative use for palm oil as a fuel substitute would be advantageous. As many experts predict, Indonesia will be a net importing oil country in 20 years if the current usage of fossil fuel stays as it is and there is no new discovery of oil reserves. Therefore, biodiesel will play an important role in Indonesia's energy sector. Not only will it serve as an instrument to control the Indonesian CPO stock, but it will also reduce fossil fuel dependency and strengthen national energy security. The study should also endeavour to avoid or minimize creating other problems such as deforestation and air pollution due to aggressive development of biodiesel from oil palm. Furthermore, recognizing the importance of government's role and the participation of other palm oil stakeholders to the success of biodiesel development, concrete partnership based on a mutual interest is crucial. The initiative to build mini-biodiesel plant has served as an example of cooperation among the biodiesel Stakeholders for the further development of this fuel in.

According to Hasan Aydogan, Mario Hirz, Helmut Brunner/ International Journal of Social Sciences Vol. III (4), 2014(12)

Due to their positive effects on exhaust gas emissions, especially on the reduction of the greenhouse gas (CO2) emissions, biofuels show a great potential in present and the future. The development of second, third and fourth generation of biofuels will increase the efficiency in production and reduce the drawbacks, e.g. the influence of biofuel industry on food-production. A broad variety of different types of biofuel enables the development of fuels with specified characteristics according to the requirements of engine exhaust gas after treatment technology.

According to CheHafizan and Noor Zainon Zainura/ Journal of Environmental Research And Development Vol. 7 No. 4, April-June 2013(13)

Results for these biofuels in general shows that bioethanol and biodiesel present better environmental performance than fossil fuel for parts of important environmental categories such as global warming, fossil depletion and ozone layer depletion. However, there are environmental impact categories where biofuel shows poor environmental performance than fossil fuel such as in terms of acidification, eutrophication, photochemical oxidation, and agricultural land use. The selection of environmental impacts categories to be prioritized depends on which impacts are the most sensitive to the region and are also related to the society's perception about these environmental impacts.

According to Abdolsaeid Ganjehkaviri / Energies 2016, 9, 97; doi: 10.3390/en9020097 (14)

Combustion experiments were conducted using PME (palm methyl ester) CDF (conventional diesel fuel) and blends of PME with CDF (B10, B20 and B40). The combustion performance of PME was compared to diesel under various conditions. From the results, it was found that the density, viscosity and surface tension of fuels increased as the percentage of palm biodiesel in the blends increased, while the calorific value of the fuels decreased as the percentage of palm biodiesel in blends increased. The inside temperature of the chamber was reduced when palm oil-based biodiesel content increased in the fuel blends. This means palm oil-based biodiesel combustion generates lower temperatures inside the chamber compared to diesel fuel. Besides, the enhancement of volumetric fuel flow rate raises the combustion temperature. Palm oil-based biodiesel showed lower gas emission (NOx and CO) compared to diesel fuel. Increasing the volumetric fuel flow rate in the combustion generates higher rates of gas emissions. High NOx formation occurs for lean mixtures with high nitrogen presence and sufficient temperature, whereas high CO occurs in rich mixtures with low oxygen presence.

According to M.F. Demirbas et al. / Energy Conversion and Management 50 (2009) 1746–1760(15)

Bio-energy currently contributes to 10–15% (approximately45 EJ) of world energy use and several countries have established targets for the use of fuels produced from biomass. Various scenario studies suggest potential market shares of modern biomass till the year 2050 of about 10–50%. Utilization of biomass resources will be one of the most important factors for environmental protection in the 21st century. Biomass absorbs CO2 during growth, and emits it during combustion. Therefore, biomass helps the atmospheric CO2 recycling and does not contribute to the greenhouse effect. Biomass consumes the same amount of CO2 from the atmosphere during growth as is released during combustion. In addition, overall CO2 emissions can be reduced because biomass is a CO2 neutral fuel.

According to Rajendra Beedu/ International Journal of Current Engineering and Technology (16)

Food waste is a very good substitute for L P G gas because India is self-reliant in food production and crude oil is imported. A regular feeding of biogas plant with proper amount will ensure consistent release of biogas and ensures uninterrupted production of gas. Even if the plant is not fed for one or two days, (Saturday and Sunday in a school), the efficiency of the plant is not affected Crushed and blended food improves the liberation of biogas as digestion becomes easy. Underfeeding or overfeeding of plant should be avoided. Underfeeding keeps the plant inefficient and overfeeding increases the Ph value of food waste and reduces the development of microbes. The payback period is small. Hence affordable in schools and small canteens. The local distribution system in any small location between plants and hotels ensures continuous supply of food waste with an added advantage of reduction in environmental hazards. Food provided under mid-day meal is simple and mostly rice so a simple single stage digestion process is sufficient and effective.

According to Jiang Chang-qiu, Liu Tian-wei &Zhon Jian-li / Biomass 20(1989) 53-59(17)

Through experiments and analysis it is proved that the application of biogas as a fuel for dual- fuel diesel-biogas engines is feasible and economical. The oil saving achieved by connecting high pressure biogas directly into the engine is less than that of connecting low pressure biogas. And stronger knocking is produced by engine connecting high pressure biogas as compared to low pressure biogas.

According to Debabrata Barik (IJETAE) 2013 193-202(18)

Water scrubbing is a simple continuous and cost effective method. This gives 87.6% and 100% pure methane with biogas flow rates of 2 m^3/hr and 1.8 m^3/hr respectively. Study shows that Monsanto and acetate cellulose membranes give best separation to CO_2, O_2 and H_2S at pressure and temperature of 5.5 bars and 25$^{\circ C}$. Cryogenic separation gives 97% pure methane by condensing CO_2 at -45 $^{\circ C}$. In biogas SI operation, the thermal efficiency is improved from 26.2% to 30.4%, when there is 21% reduction of CO_2 in biogas. Dual fueling is recommended to be the best one for biogas CI operation. Drop of 15% CO2 in biogas for dual fueling increases the thermal efficiency of 22%. Also the HC and smoke level are reduced significantly.

According to Mustafa Balat/ Energy Conversion and Management 52 (2011) 1479–1492 (19)

The edible vegetable oil fuels were not acceptable because they were more expensive than petroleum fuels. Non-edible plant oils have been found to be promising crude oils for the production of biodiesel. Throughout the world, large amounts of non-edible oil plants are available in nature. Some of non-edible oilseed crops include jatropha tree (J. curcas), karanja (P. pinnata), tobacco seed (N. tabacum L.), rice bran, mahua (M. indica), neem (A. indica), rubber plant (H. brasiliensis), castor, linseed, and microalgae. Waste cooking oils offer a significant potential as low-cost raw material for biodiesel production. The price of waste cooking oil is 2.5–3.5 times cheaper than virgin vegetable oils, thus can significantly reduce the total manufacturing cost of biodiesel. As large amounts of waste cooking oil are illegally dumped into rivers and landfills, causing environmental pollution, the use of waste cooking oil to produce biodiesel as petroleum-based diesel fuel substitute offers significant advantages because of the reduction in environmental pollution

3. Description of Experimental Set up

The engine used for the present investigation is a single cylinder, four strokes, water cooled diesel engine which is coupled to the brake dynamometer. It is provided with a board on which the display units and other measuring instruments like rotameter, U-tube differential manometer, and burette setup are given. The experimental setup has air-box, fuel tank, calorimeter, modified convergent-divergent nozzle etc. The loading arrangement is also provided in the experimental setup through brake dynamometer. Diesel is filled in the diesel tank which is placed in above of the panel board. A burette is also placed in the panel board which is used to measure fuel consumption. When engine is start valve of the fuel tank is closed and open valve of the burette. This burette one side is open to fill Biodiesel in different proportion and another side is fitted in the valve. Biogas is supplied to the engine at air supply line, through convergent-divergent nozzle. Biogas consumption is calculated by measuring weight of biogas by weight measuring device. The fuel flow rates are measure by noting time taken for 1 min. Present study performs in thermal engineering lab in UIT RGPV Bhopal (M.P.) .

Figure 3.1 Experimental setup of diesel engine (i) Front view (ii) Side view (at UIT-RGPV BHOPAL)

Modified Experimental Setup

Biogas generally has a high self-ignition temperature hence; it cannot be directly used in a CI engine. So it is useful in dual fuel engines. The dual fuel engine is a modified diesel engine in which usually a gaseous fuel called the primary fuel is inducted with air into the engine cylinder. This fuel and air mixture does not auto ignite due to high octane number. A small amount of diesel, usually called pilot fuel is injected for promoting combustion. Dual fuel engine can use a wide variety of primary and pilot fuels. The pilot fuels are generally of high cetane fuel. Biogas can also be used in dual fuel mode with vegetable oils as pilot fuels in diesel engines. Injectors opening pressure and rate of injection also are found to play important role in the case of biogas fuelled engine, where vegetables oil is used as a pilot fuel. Thus a fuel with low self-ignition temperature could be used along with biogas to help its ignition

Table 3.1: Engine specifications

Parameter	Details
Engine	Vertical engine, Kirloskar
Engine Nature	4 stroke single cylinder direct injection CI engine
Type	Water cooled
Brake power	3.7KW
Number of cylinders	1
Bore	80mm
Stroke	110mm
Rated speed	1500rpm (constant)
Combustion	Compression Ignition
Air flow measurement	Air box
Torque measurement	Brake dynamometer
Radius of dynamometer flywheel	0.30 m

Biogas mixer

It is a device which is used for proper mixing of air and biogas. Air is allowed to pass through a constriction; in dynamics, a passes through in according with the principle of continuity, while its static pressure must drop as the principle of conservation of mechanical energy. Thus, any gain in kinetic energy a fluid may increase due to its increased velocity through a constriction is balanced by a drop in pressure. At constriction, the velocity of air is very high hence; biogas is introduced in this narrow pass for proper mixing (figure 3.2 & 3.3)

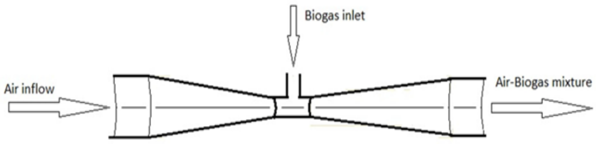

Figure 3.2 Principal image of Biogas mixer

Figure 3.3 Image of Biogas Mixture in UIT-RGPV Diesel Engine

Gas Storage Tube and Air Compressor

First biogas is generated in biogas plant after that it store in tube with help of Air compressor. Air compressor is mainly hand operated.

Figure 3.4 Air compressor, Biogas Storage Tube and Its Connection with Engine

Power measurement (Brake dynamometer)

A dynamometer consists of an absorption (or absorber/driver) unit, and usually includes a means for measuring torque and rotational speed. An absorption unit consists of some type of rotor in housing. The rotor is coupled to the engine or other equipment under test and is free to rotate at whatever speed is required for the test. Some means is provided to develop a braking torque between the rotor and housing of the dynamometer. The means for developing torque can be frictional, hydraulic, electromagnetic, or otherwise, according to the type of absorption/driver unit.

Figure 3.5: Brake dynamometer

Figure 3.6: Temperature display

Temperature measurement

The thermocouple is a simple, widely used component for measuring temperature. A thermocouple consists of two wires of dissimilar metals joined together at one end, called the measurement ("hot") junction. The other end, where the wires are not joined, is connected to the signal conditioning circuitry traces, typically made of copper. This junction between the thermocouple metals and the copper traces is called the reference ("Cold") junction. Six thermocouples (K-type) are fitted at relevant positions for the measurement of temperatures at the required positions. Temperature display unit shown in fig 3.6

4. Production of Biofuels

Production of the Biodiesel

Biodiesel is fatty acid alkyl ester. It can be produced by transesterification process of palm oil, vegetable oils, animal fats and waste oils. It has similar composition and properties as that of petroleum diesel. The Biodiesel used in this experiment is produced from the palm oil. The palm oil is obtained from the palm tree seeds. The phenomenon of replacement of an alcohol by a different alcohol from an ester is known as transesterification, the process of transesterification is also known as alcholysis. By the help of this process we reduce down the viscosity of triglycerides. The general equation of transesterification is

RCOOR' + R"OH ↔ RCOOR" + R'OH

In the above reaction if methanol is used, it is termed methanolysis. The Biodiesel can be produced by the transesterification or alcoholysis. Raw Palm oil must be treated before transesterification process. Raw oil having less than 5% free fatty acid need not require pre-treatment. The alkali catalyst KOH and methanol added to the 100 ml palm in the ratio of (3 gram KOH and 12ml methanol) and heated up to temp 65°C for 2 hours after that separated with help of separating funnel.. In this study the transesterification reaction is conducted in the presence of base catalyst. The mechanism of alkali-catalyzed transesterification is described below. The first step is the attack of the alkoxide ion to the carbonyl carbon of the triglycride molecule, which results in the formation of tetrahedral intermediate product. In the second step, this intermediate product reacts with an alcohol and produces the alkoxide ion.

Biogas generation method

Biogas is produced by extracting chemical energy from organic materials in a closed and well-sealed container called a digester. The Biogas generation is a concept of anaerobic digestion i.e. known as biological gasification. Biological gasification is microbial process which occurs in nature in the absence of oxygen transforms organic substance into methane, carbon dioxide and other products. The chemical reaction takes place in the presence of methanogenic bacteria with water an essential medium. The anaerobic digestion process, as the name states, is one that functions without molecular oxygen. Ideally, in a biogas plant there should be no oxygen within the digester. Oxygen removal from the digester is important for two main reasons. First, the presence of oxygen leads to the creation of water, not methane. Second, oxygen is a contaminant in biogas and also a potential safety hazard. Due to presence of oxygen and other constituent, calorific value of biogas becomes low.

5. Experimental setup of Biofuels production

Experimental setup of Biodiesel production

The experimental setup for production of Biodiesel palm oil consist of reactor has a capacity of 1 litre with a hot plate and a beaker of 1 litter capacity shown in the figure.

Figure 5.1 photographic image of magnetic stirrer with hot plate and Separating funnel for biodiesel separation at Mechanical Lab UIT- RGPV Bhopal

Materials required for biodiesel production

- Feedstock: palm oil,
- Base Catalyst: KOH 1% w/w of palm oil,
- Reactant: Methanol to palm oil-molar ratio is 13%
- Reactor with Electric power and timer
- Hot plate with magnetic stirrer
- Separating funnel
- Stands

Biogas production plant

Biogas is a clean and efficient fuel, generated from cow-dung, human waste or any kind of biological materials derived through anaerobic fermentation process. The biogas consists of 60% methane with rest mainly Carbon-Di-oxide. Biogas is a safe fuel for cooking and lighting. By-product is usable as high-grade manure.

Figure 5.2 Biogas plant at UIT RGPV BHOPAL

A typical biogas system consists of the following components like Manure collection, anaerobic digester, Effluent storage, Gas handling and Gas use. Biogas is a renewable form of energy. Methanogens (methane producing bacteria) are last link in a chain of microorganisms which degrade organic material and returns product of decomposition to the environment.Agricultural Feed stock like Animal manure, Energy crops, Algal biomass, Crop residues, Manure sewage waste Sewage sludge, Grass clippings/garden waste, Food remains, Institutional wastes, Industrial Feed stock, Food/beverage processing

Table 5.1: Components of Biogas

Constituent	By volume	By mass
CO_2	19%	37.28%
O_2	1.50%	2.15%
CH_4	73%	52.34%
H_2S	20PPM	-
Density	0.915Kg/m^3	-
A/F	17.23	-

Purification of biogas

Biogas Purification Technologies

- Scrubbing
- Chemical Absorption
- Pressure Swing Adsorption
- Membrane Purification
- Cryogenic Separation
- Biological Processes

6. Results and Discussion

In this thesis work, the biogas is used in single cylinder 4-stoke compression ignition engine in different proportion where palm oil biodiesel **(100% POBD)** is used as a main fuel, engine is operates in dual fuel mode. The performance and emission characteristics of POBD with and without biogas are compared with diesel operation. Main purpose of experiment to determine fuel consumption, BSFC, Brake thermal efficiency, heat balance, and emission parameter like CO, HC CO2 on basis of brake power or load applied in neat POBD mode and also with Biogas of different proportion in duel fuel mode.

Performance parameter

Brake Specific Fuel Consumption

BSFC for Diesel (mineral) and Neat POBD with different proportion of biogas

Figure 6.1 shows the variation of BSFC with Brake Power for neat diesel and different proportions of biogas. As the proportion of biogas increases, the BSFC of the engine decreases for a particular brake power. BSFC decrease with increasing brake power in all cases. Below figure shows the BSFC is minimum for Dm+BG8 and maximum for Dm at particular brake power.

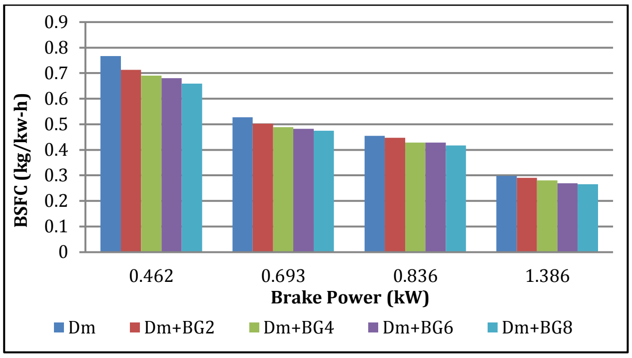

Figure 6.1

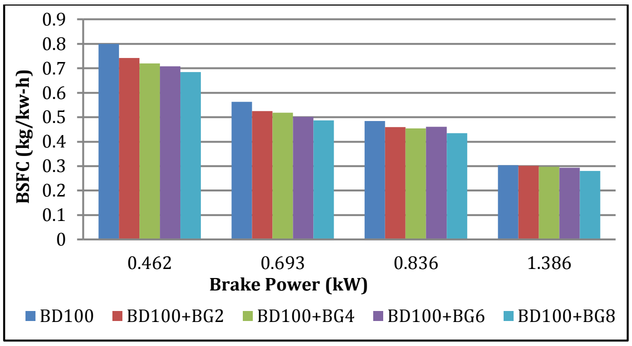

Figure 6.2

Figure 6.2 shows the variation of BSFC with Brake Power for neat POBD and different proportions of biogas. As the proportion of biogas increases, the BSFC of the engine decrease for a particular brake power. BSFC decrease with increasing brake power in all cases. Figure shows the BSFC is minimum for BD100+BG8 and maximum for BD100 at low brake power condition. Figure 6.2 and 6.3 shows variation of BSFC with brake power mono fuel mode to with biogas in dual fuel mode. When we compare diesel and biodiesel of its increasing biogas mass flow rate, BSFC is decreasing continuously because biogas contain lower calorific value.

Brake Thermal Efficiency (BTE)

BTE for Diesel (mineral) and Neat POBD with different proportions of biogas

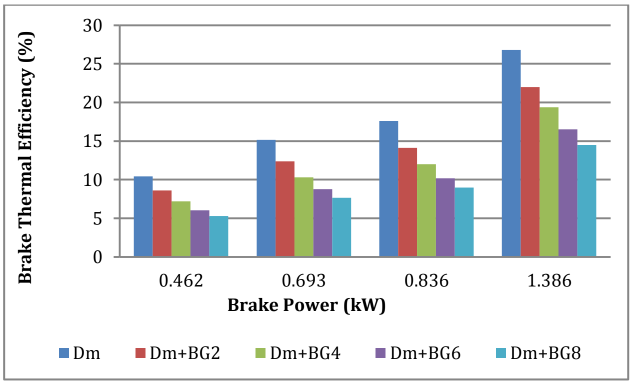

Figure 6.3

Figure 6.3 shows the variation of BTE with Brake Power for Dm and Dm with different proportions of biogas. As the proportion of biogas increases, the BTE of the engine decreases at particular brake power. While BTE increases with increasing brake power in all cases. Below figure shows the BTE is minimum for Dm+BG8 and maximum for Dm at high brake power condition.

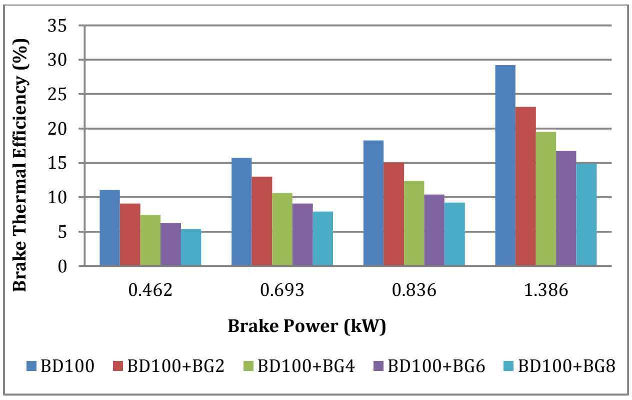

Figure 6.4

Figure 6.4 shows the variation of BTE with load for Neat POBD and POBD with different proportions of biogas. As the proportion of biogas increases, the BTE of the engine decreases at particular brake power. While BTE increases with increasing brake power in all cases. Figure shows the BTE is minimum for BD100+BG8 and maximum for BD100 at high brake power condition These charts indicate when increasing mass flow rate of biogas brake thermal efficiency is decreasing continuously because carbon dioxide (CO_2) present in biogas. To increasing the mass flow rate of biogas cool the engine because of present in CO_2.

Emission parameters

Hydrocarbon (HC) emission

HC emissions for Diesel and Neat POBD with Biogas

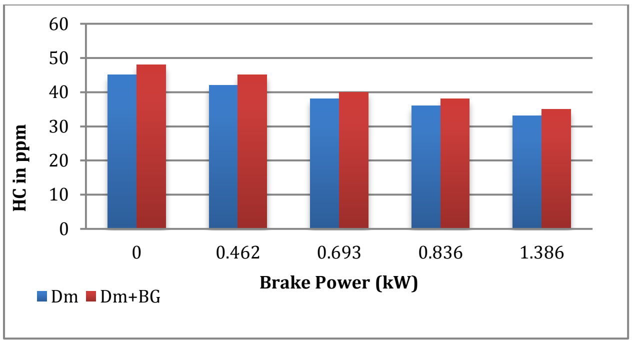

Figure 6.5

Figure 6.5 show the concentration of HC emission in dual fuel operation is considerably higher than that of diesel under all brake power conditions. This higher HC emission is due to the incomplete combustion of the fuel. The biogas induction through the intake manifold reduces the volume of inducted air hence the combustion takes place with less oxygen resulting in higher HC emission.

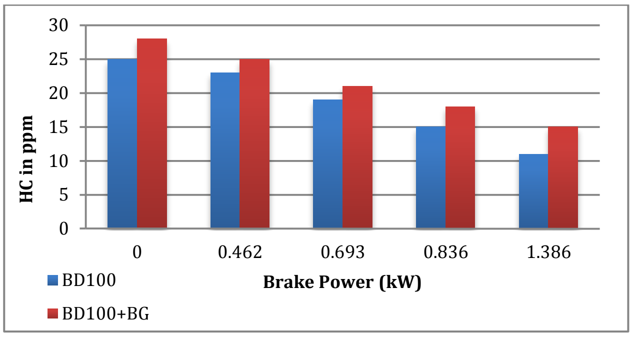

Figure 6.6

Figure 6.6 show the concentration of HC emission in dual fuel operation is considerably higher than that of POBD under all brake power conditions. This higher HC emission is due to the incomplete combustion of the fuel. The biogas induction through the intake manifold reduces the volume of inducted air hence the combustion takes place with less oxygen resulting in higher HC emission. These charts indicate when engine runs mono fuel mode emits less HC in compression of when engine runs to induction biogas in dual fuel mode in different brake power. When induction of biogas into the engine, CO_2 content in combustion chamber is increases at the expense of fresh air which is reduces the air-fuel ratio and combustion temperature.

Carbon dioxide (CO_2) emission

CO_2 emission for Diesel and Neat POBD with Biogas

Figure 6.7 shows the comparison between CO_2 emissions in single fuel mode with duel fuel mode for diesel engine. The dual fuel mode shows a lower CO_2 emission compared to single fuel operation at all brake power. This is due to the deficiency of oxygen lower combustion temperature and less time for combustion. This leads to incomplete combustion causing less CO2 emission. As the brake power increases CO2 emission decreases for both fuels.

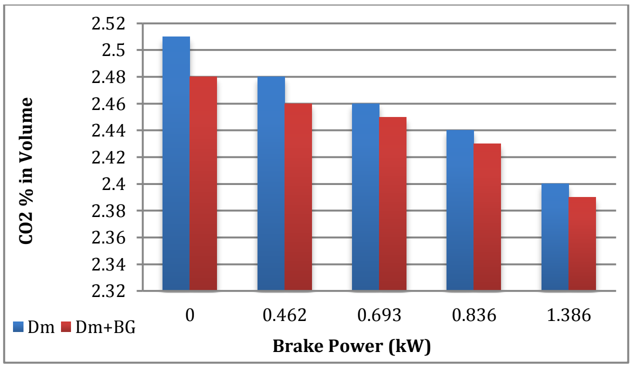

Figure 6.7

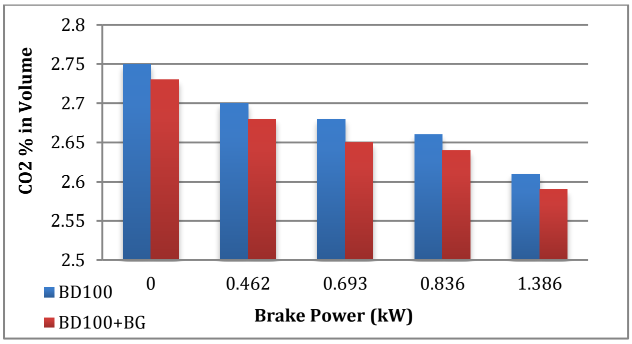

Figure 6.8

Figure 6.8 shows the comparison between CO2 emissions in single fuel mode with duel fuel mode for POBD. The dual fuel mode shows a lower CO_2 emission compared to single fuel operation at all brake power. This is due to the deficiency of oxygen lower combustion temperature and less time for combustion. This leads to incomplete combustion causing less CO2 emission. As the brake power increases CO2 emission decreases for both fuels. These charts indicate when engine runs mono fuel mode emits more CO_2 in compression of when engine runs to induction biogas in dual fuel mode in different brake power. When induction of biogas into the engine for combustion, the combustion chamber less availability of oxygen and low combustion temperature, Due to deficiency of oxygen incomplete combustion take place and emits less CO_2.

Carbon monoxide (CO) emission

CO emission for Diesel and Neat POBD with Biogas

Figure 6.9 and 6.10 show comparison between single and dual-fuel combustions, the concentrations of CO emissions for the dual-fuel mode considerably higher than those of the single-fuel mode under all brake power conditions. With the inducing of gaseous fuel (biogas), which means the increasing of the CO_2 content in the mixture instead of fresh-air, turbulent flame propagation from the ignition regions of the pilot is normally suppressed due to the lower temperature and air–fuel ratio, and it will not proceed until the concentration of the gaseous fuel reaches a minimum limiting value. Also, it has been reported that the ignition is normally more delayed with dual-fueling compared to diesel fueling. In addition to these mechanisms, there were contributions from crevice volumes in which the gas–air mixture was forced into during compression and where it then remains unburned. As brake power increases CO emission decreases for all cases.

Figure 6.9 and 6.10 shows the variation of the CO emission with Brake power of diesel and biodiesel mono fuel mode and its combine with biogas in dual fuel mode. These charts shows when engine is run single fuel mode CO emission are less as compared to when engine run in pilot fuel with biogas in dual fuel mode. In engine when supply the biogas, these contains large amount of CO2, so incomplete combustion is take place in combustion chamber. Now this incomplete combustion CO emission is more than single fuel mode.

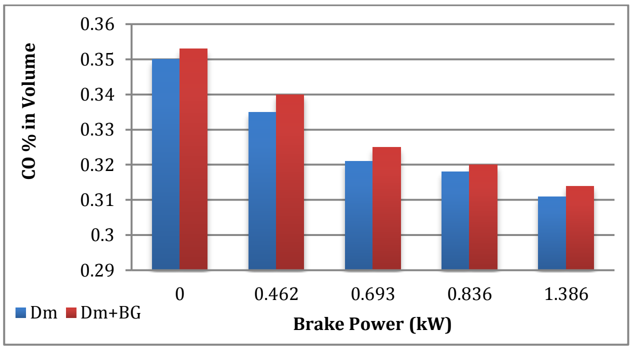

Figure 6.9

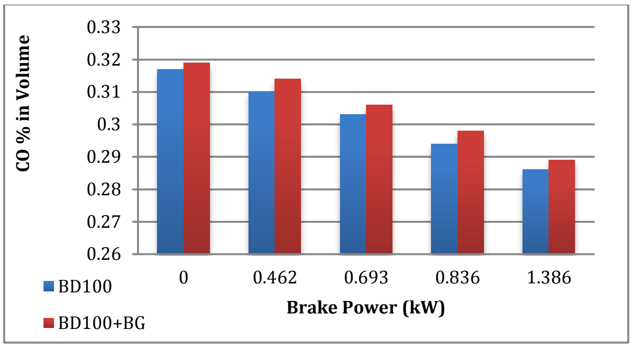

Figure 6.10

Conclusion

This study is based on to determine best alternative biofuels **(POBD and Biogas)** in place of conventional diesel fuel and their performances and exhaust emission analysis in single fuel mode (Neat POBD) and dual-fuel mode, for neat POBD and biogas of different proportion in a single cylinder four stroke diesel engine under various load or brake power conditions because it is constant in our experiment. The following conclusions were taken from the analysis:

- Palm oil biodiesel **(POBD)** is best fuel compare to other vegetable oil because of its adequate availability, lower cost also it forms 33% of world vegetable oil production and biogas are easily made by waste food and rural waste as renewable source of energy in India and which can be utilized in CI diesel engine in single or dual mode without any major changes in the engine design.
- The BSFC in duel fuel mode, at low brake power condition more for neat POBD compare to diesel but as the amount of biogas is increases in BD100, BSFC of (BD+BG) decreases proportionally because biogas contains some lower calorific value. At high load condition BSFC is low in all cases.
- The BTE in duel fuel mode, more for BD100 but as the proportion of biogas increases the BTE of the

engine decreases continuously because carbon dioxide (CO_2) present in biogas. To increasing the mass flow rate of biogas cool the engine, in all brake power condition. At high brake power BTE is high in all cases.

- CO emission in duel fuel mode, considerably higher than those of the single-fuel mode under all brake power conditions. With the inducing of gaseous fuel (biogas), which means the increasing of the CO_2 content in the mixture instead of fresh-air. As brake power increases CO emission decreases for both fuel modes.
- HC emission in dual fuel operation is considerably higher than of neat POBD under all brake power condition. Because when introduce biogas with fresh air incomplete combustion take place. As load increases HC emission decreases.
- The dual fuel mode shows a lower CO_2 emission compared to single fuel operation at all brake power. This is due to the deficiency of oxygen lower combustion temperature and less time for combustion. This leads to incomplete combustion causing less CO2 emission. As the brake power increases CO2 emission decreases for both fuels.

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