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Experimental Study on 100% Replacement of Fossil Fuel by the Biofuels

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Abstract:
In present scenario, India is facing severe problems of energy crisis due depletion of fossil fuels which made price hike in the global market, now it is time to switch over the alternate sources of energy to meet and match with present and future energy demands of our nation. Biofuels like biogas and biodiesel are the better alternative fuels; they are renewable, cost effective and environment friendly. As India is an agriculture based country a lot of sources are available for biomass to obtain gaseous fuel like biogas. In this tropical country karanja tree is also found in plenty.Karanja oil Biodiesel can be obtained from transesterification process of the karanja seed oil, which is non-edible oil; hence it can be used in power generation. Present study was carried on 100% replacement of fossil fuel by the biofuel which can save import expenditure and improve our GDP. In this regard, single cylinder four stroke diesel engine was modified to run in dual fuel mode (Biogas & Biodiesel) and analysed the performance parameters like FC, BSFC, BTE and emission parameters like CO2,HC and found comparable values of such parameter with traditional diesel fuel. The results indicated that under dual fuel mode i.e. biodiesel-biogas mixture has lower brake thermal efficiency than that of the mono fuel mode run on neat biodiesel. An overall evaluation of the results indicated that the biogas and biodiesel dual fuel operation could be substituted in place of diesel fuel in power generation in rural areas where there is great availability of the biofuels. Possibly, it will work satisfactorily under long term operation of engine in power generation without any major troubles.

Keywords: *Fossil fuels, biofuels, karanja seeds, transesterification, biodiesel, biogas, CI engine.*

1. Introduction

The conventional sources of energy are being depleted at a faster rate and due to increase in human dependency on the conventional sources of energy; the world is heading towards a global crisis. The greatest work today is to utilize the renewable energy resources for power generation. India, import about 80 per cent oil from outsides to meet our needs, and spent US$ 112.748 billion in 2014-15 on import of 189.43 million tonnes of crude oil. In rupee terms, it came to Rs 687,369 crore.India is now the world's third largest importer of crude oil after the United States (USA) and China.The country's oil imports have steadily climbed along with its growing economy. Since, its transport and industrial sector primarily fossil fuel driven. This import of conventional fuel is the prime reason of the fiscal deficit of our country. If we utilize renewable source of energy like the biofuels in power generation we can contribute to GDP of our country. Biofuels can be the best alternate source of energy to petroleum fuels in tropical country like India which has agriculture as its primary sector.

1.1. Production of Karanja Oil Biodiesel

India is a tropical country and avails most favourable climate for the growth of karanja tree. It is found in abundance in rural areas and woods of whole India, especially in eastern part of India and Western Ghats. Another name of the karanja is pongamiapinnata. The raw karanja oil was obtained from karanja seeds and then it was subsequently converted into its respective biodiesel i.e., karanja oil methyl ester.Fig.1 shows the close view of karanja seeds. The seeds are crushed in expeller to acquire the oil. Anoutlook of raw oil obtained by the process of crushing the seeds has been given in Fig.2 As the tree of karanja is naturally found in forest, there is so far no reports on adverse effects of karanja on fauna, flora, and humans or even on environment but that is a different area of research. Karanja oil is non-edible and hence further encourages its application for biodiesel production.

Figure 1: Seeds of karanja

Figure 2: Oil expselled from seeds of karanja.

Figure 3: Biodiesel Reactor at UIT-RGPV

Biodiesel is fatty acid alkyl ester obtained by transesterification process of vegetable oils, animal fats and waste oils. It has similar composition and properties as that of petroleum diesel. The replacement phenomenon of an alcohol by a different alchohol 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

$$RCOOR' + R''OH \leftrightarrow RCOOR'' + R'OH$$

Where,
R, R' &R" denote Alkyl or Aryl group

In the above reaction if methanol is used, it is termed methanolysis. Fig 3 shows the image of the reactor in which the tansesterification process took place. Raw materials required:

- Karnaja seed oil
- Lye (Catalyst)
- Methanol
- Isopropyl Alcohol (for tests. Use 99% IPA)

Property	**Karanja Methyl Ester**	**Diesel**
Density	885kg/m^3	836kg/m^3
Kinematic viscosity	5.6 c stoke	3.8 c stoke
Flash point	172^{0}C	56^{0}C
Fire point	223^{0}C	63^{0}C
Heating value	41200kJ/kg	44000kJ/kg
Specific gravity	0.876	0.85

Table 1: properties of oil after esterification

1.2. Production of Biogas

Biogas is produced by anaerobic digestion. Anaerobic digestion is process of biochemical degradation, in which organic matters such as biomass, manure, sewage, municipal waste, green waste, plant material and crops which are biodegradable are decomposed by bacteria forming gaseous by product. The by product is comprising of methane (CH4), carbon dioxide (CO2), and traces of other gases It is a naturally occurring, microbial process in absence of oxygen The chemical reaction takes place in the existence of methanogenic bacteria with essential medium water in the absence of oxygen to yield methane. Biogas would be attractive just where it is close to production site.

Composition	Amount (%)
Methane (CH_4)	50-70
Carbon dioxide (CO_2)	30-40
Hydrogen (H_2)	5-10
Nitrogen (N_2)	1-2
Water vapour (H_2O)	0.3
Hydrogen sulphide (H_2S)	Traces

Table 2: Composition of biogas

Figure 4: Biogas Digester

Fig.4 shows the image of the biogas digester which generates biogas, whose working principle is anaerobic digestion. Biogas can be cleaned and improved to natural gas standards and becomes bio methane. This idea of biogas as a diesel substitute is not novel, but it is a very striking and efficient alternative, particularly in countries having more work on agricultural products and demand of petroleum resources. There have been persistent efforts in research work for alternative fuel resource, development and demonstration to consume biogas to provide heat and power. Biogas can be used as an alternative to the partial substitution of diesel fuels without demanding extensive engine alterations or modifications.

→ Biogas Storage: We stored biogas for onsite use. Biogas was directly injected into the engine from digester. The other way is one in which earlier and after moving to offsite delivery points, based on this they can be stored at low (up to 0.137 bar), medium (between 0.137-13.78 bar) and high pressure (between 137.89 bar and 344.73 bar).

1.3. Experimental Setup for Performance Analysis:

1.3.1. Experimental Setup

The experimental setup used for this study was based on a vertical, 4- stroke, single cylinder, constant speed, direct injection, compression ignition and water cooled engine. It has a bore of 80 mm, a stroke length of 110 mm, a displacement volume of 553 cm^3 and a compression ratio of 16.5:1.The rated maximum power was 3.78kW at 1500 rpm. The engine was coupled with a brake dynamometer to apply load. The setup has detached air box, fuel tank, hot wire anemometer, fuel measuring unit, temperature measuring unit etc. The fuel tank is positioned in the panel board which injected the fuel in the engine. The burette was also positioned in the panel board which is used to measure the fuel in the engine. Biogas is admitted to the engine via fuel pipeline, through biogas mixing device. We had attached a hot wire anemometer in the biogas pipeline to measure the velocity of the biogas. This velocity is used in the calculation of mass flow rate of biogas. Existing work performed in thermal engineering lab of UIT RGPV Bhopal (M.P.), fig 5 is the image of experimental setup. The schematic block diagram of experimental setup and instruments used for measuring the performance parameters and emission are shown in fig 6. The main aim of this experiment is to investigate the effect on performance of modified diesel engine to run on duel fuel mode with the usage of karanja oil biodiesel and biogas .Performance investigation of duel fuel on diesel engine were evaluated at different load condition and at constant speed.The test is conceded out onengine by using biogas as a fuel with few additional components and modification, which is required for better performance in compression of the experiment engine. The engine specifications are given in Table 3 and block diagram of the experimental setup is shown in Figure 6.

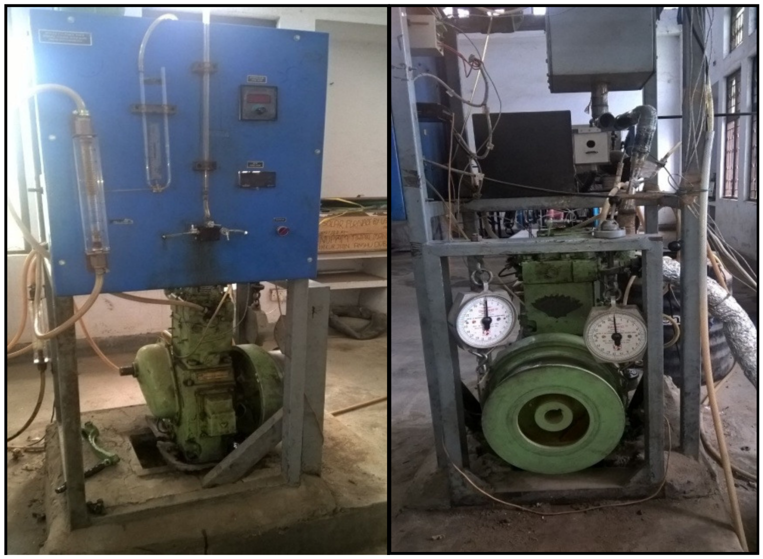

Figure 5: Experimental set at UIT –RGPV

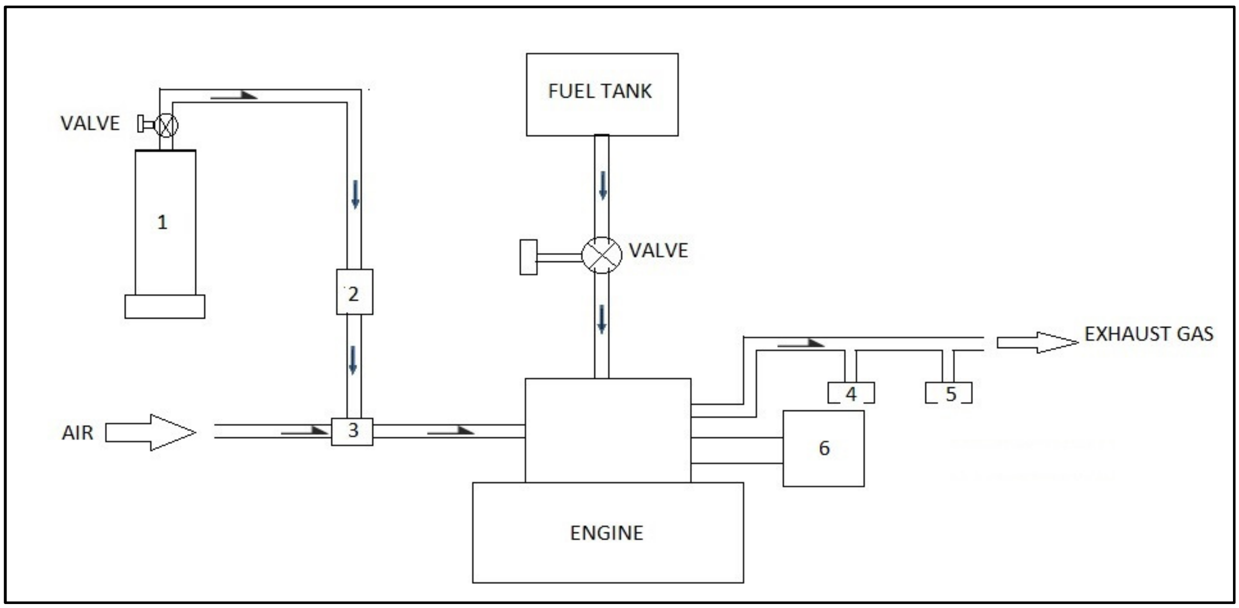

Figure 6: Schematic diagram of the experimental setup

1.Biogas container, 2.Biogas flow velocity measuring device (Hot wire anemometer), 3.Air-Biogas mixing device, 4.Calorimeter, 5.Exhaust gas analyser, 6.Dynamometer.

Engine	**Kirloskar**
Engine Nature	4 stroke single cylinder direct injection CI engine
Type	Water cooled
Brake power	3.7 KW
Number of cylinders	1
Bore	80 mm
Stroke	110mm
Rated speed	1500 rpm (constant)
Combustion	Compression Ignition
Air flow measurement	Ari box

Table 3: Engine specifications

Biogas directly cannot be used to run a CI engine on account of its high self-ignition temperature. Though, it can be consumed in a CI engine with the dual fuel approach. The dual fuel engine is basically a modified CI engine. Duel fuel technology mainly consists of two fuels. One which is gaseous fuel, on which the engine runs primarily, is called as primary fuel and the other fuel which is used to initiate the ignition is the pilot fuel. In this case, a mixture of air and biogas is sucked into the engine, compressed and then ignited by a spray of fuel with a low self-ignition temperature such as diesel, vegetable oil or bio-diesel, which is called a pilot fuel. Dual fuel operation always needs a small amount of pilot fuel for ignition To operate diesel engines with biogas and biodiesel, can be suitably converted to a dual fuel engine, which is the most efficient and practical method. Since biogas consists of a high octane number, it can be utilized in a high compression ratio engine to maximize its conversion efficiency. The supplementary components required for biodiesel-biogas duel fuel operation are: Hot wire anemometer, Biogas mixing device, four gas analyser.

1.3.2. Hot Wire Anemometer

It is an instrument used for the measurement of air velocity; in this setup it is used for the measurement of the inlet velocity of the biogas coming from biogas digester through pipe. The general hot wire anemometer is made up of a sensor; a small wire uncovered to the fluid flow is electrically heated and electronic equipment to execute the transformation of the sensor output into electrical signals. The working principle of hot wire anemometer is that when the flow velocity passing the thin wire which is a sensor, the convective heat transfer will vary, wire temperature will change and it will increase the resistance in the wire. Hot wire anemometer current inside across filament is measured. There are two models of operation of hot wire anemometers such as for constant current and constant temperature. In constant current type model, there is a variation in wire resistance.

Figure 7: Hot wire anemometer

W=Q+dQi/dt

Where,

W: Power generated by joule heating given i2RW

Where RW=RW (TW);

Q: Heat transfer rate to surrounding;

Qi: Stored Thermal energy in the wire (CWTW);

RW: Resistance of the wire;

CW: Heat capacity of the wire;

TW: Temperature of the wire

1.3.3. Biogas Mixing Device

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.

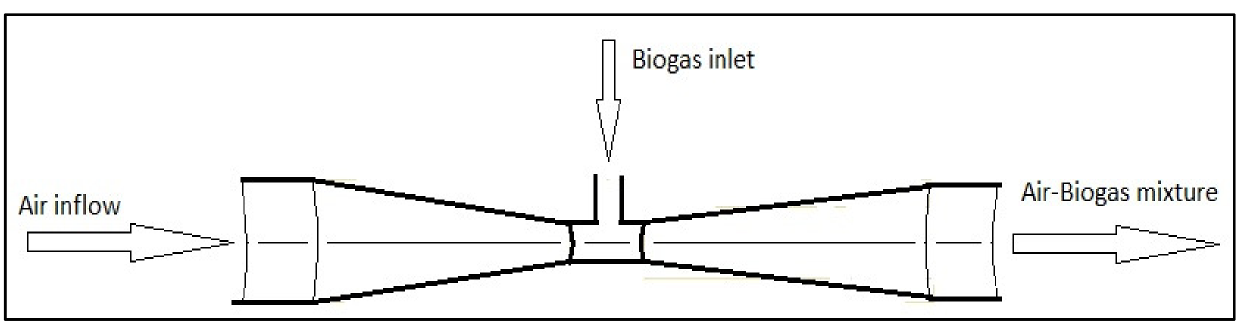

Figure 8: Biogas mixing device

2. Result and Discussion

In this research work, an effort has been made to compare the performance and emission characteristics of a CI engine when operated with karanja oil biodiesel (BD) in single mode and karanja oil biodiesel - biogas (BD+BG) in dual fuel mode. Loading arrangement is used to apply loads by the brake dynamometer.

2.1. Load vs. Fuel Consumption

Figure 9 shows the variation of fuel consumption with load for neatbiodiesel & biodiesel-biogas mixture and neat diesel. The fuel consumption of the engine is increased with the increase of load. From the fig.9, it is observed that the fuel consumption of the biodiesel is less when biogas is used as the fuel in duel fuel mode with biodiesel as the pilot fuel because the proportional replacement of the biodiesel by biogas is taken.

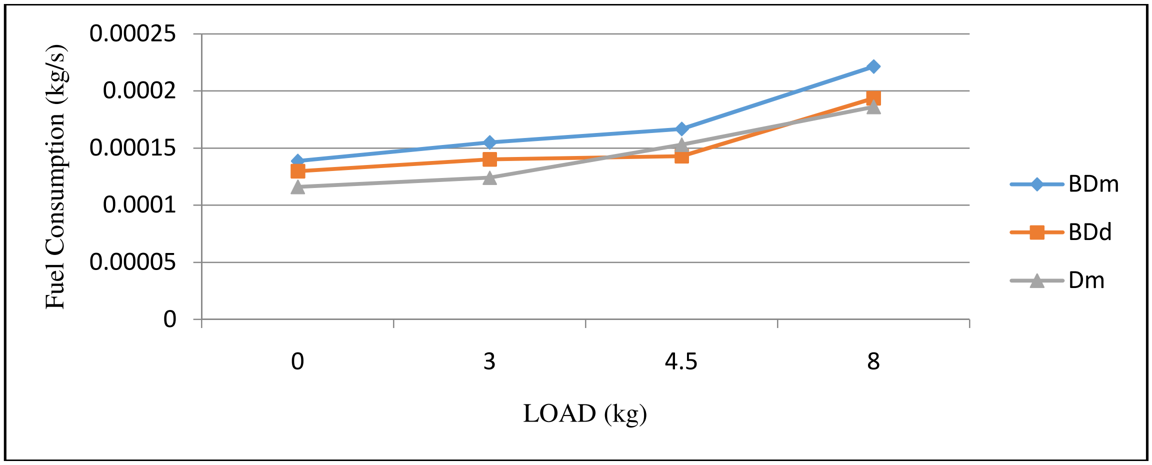

Figure 9: Shows a Comparison of consumption of biodiesel in mono & duel fuel mode with diesel in mono fuel mode.

2.2. Load vs. Brake Specific Fuel Consumption

Fig 10 shows the variation of Brake specific energy consumption with Brake power for neat biodiesel and biodiesel-biogas mixture. BSEC decreases with increasing load in both cases whereas in case of neat biodiesel it was higher than the dual fuel mode because biogas is the low heat content gas. From the graph, it is observed that the Brake specific energy consumption from biodiesel is lessas compared to BSEC of biodiesel in dual fuel mode of operation, because the some proportional replacement of the biodiesel by biogas is taken place. The BSEC of biodiesel in dual fuel mode is near to the BSEC on diesel in mono fuel mode.

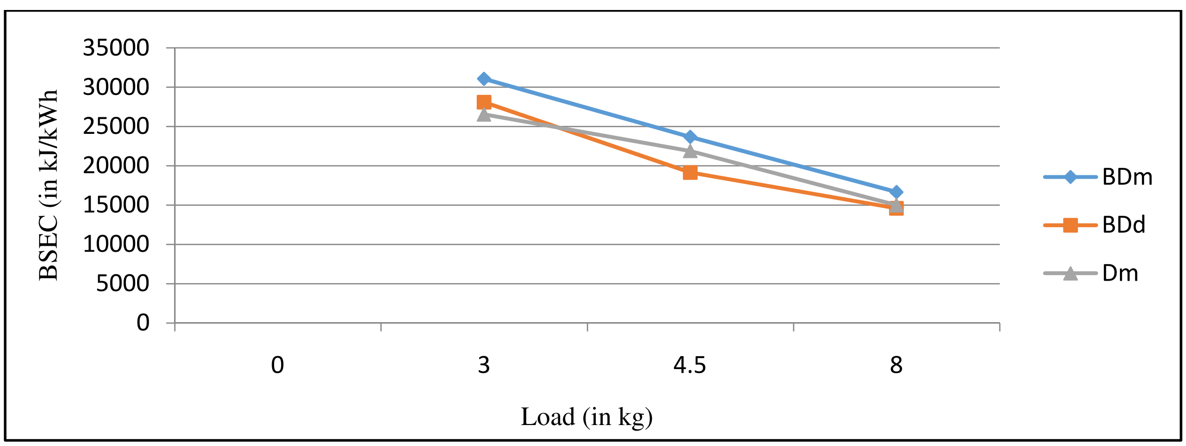

Figure 10: Load vs. Brake Specific Fuel Consumption

2.3. Brake Thermal Efficiency

The Fig.11 shows the variation of Brake thermal efficiency with load for neat biodiesel in mono fuel mode and biodiesel-biogas mixture in duel fuel mode. The brake thermal efficiency indicates the ability of the combustion system to accept the investigational fuel and provide comparable means of evaluating how efficiently energy in the fuel can be converted into mechanical productivity. If we use biodiesel-biogas mixture as fuel in duel fuel mode, then the brake thermal efficiency will be lower when compared to neat biodiesel in mono fuel mode because due to carbon dioxide content present in the biogas, lowers energy contents in biodiesel fuel with biogas.

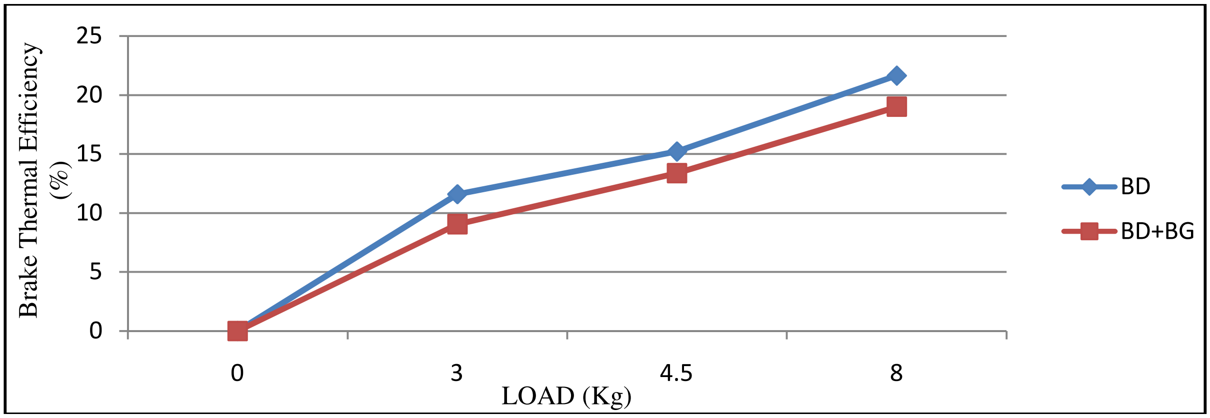

Figure 11: variation of brake thermal efficiency with load

2.4. HC Emissions

Figure 12 shows the HC emissions at different engine loads under different combustion modes. As shown in the figure, the HC emissions for neat biodiesel were lower than those of biodiesel-biogas fuel mixture in dual fuel combustion mode. The lower HC emissions for biodiesel is due to the fact that it has higher oxygen content by weight and high cetane value, which leads to better combustion in the combustion chamber. Whereas, comparing the single and dual-fuel combustions, the HC emissions for the dual-fuel mode were found to be higher than those of the single-fuel mode under different load conditions. With the induction of biogas into the engine, the CO2 content in the mixture increases at the expense of fresh air which in turn reduces the air–fuel ratio and combustion temperature.

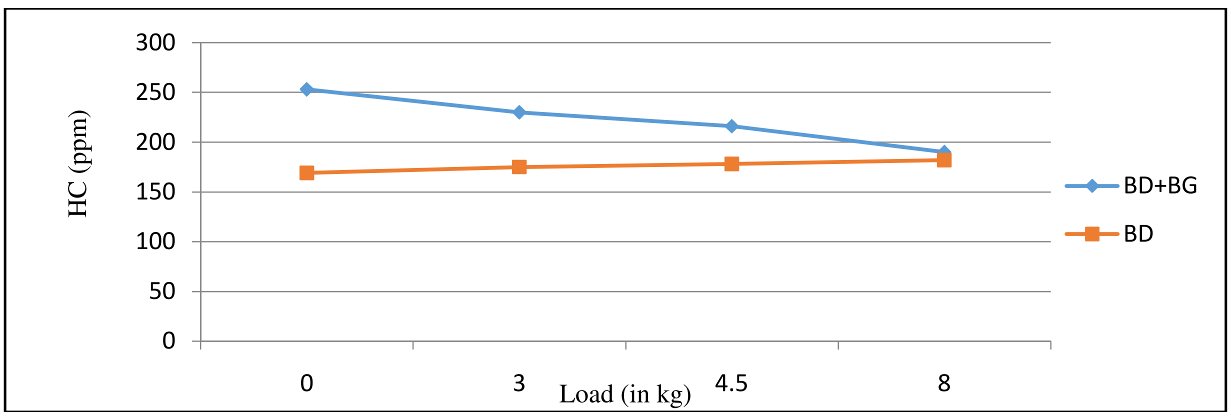

Figure 12: variation of HC emission with engine load CO_2 Emissions:

Figure 13 shows the concentrations of CO2 emissions at different engine loads for both single and dual-fuel combustion modes. In this figure, the more CO2 emissions were produced by dual-fuel combustion of biodiesel-biogas mixture due to low C/H ratio, whereas biodiesel mono fuel combustion produced the low CO2 emissions. For the comparison of test fuels, figure 13 indicates biodiesel combustion with both combustion modes generated higher concentrations of CO2 emissions. This is because of presence of oxygen in biodiesel allowing more CO to be oxidized into CO2. However, study of closed carbon life-cycle of biodiesel, the CO2 emissions exhausted from the diesel engine fuelled with biodiesel are engrossed and reused by growing plants. Therefore, biodiesel combustion can be considered as definitely causing lower net CO2 emissions than diesel fuel.

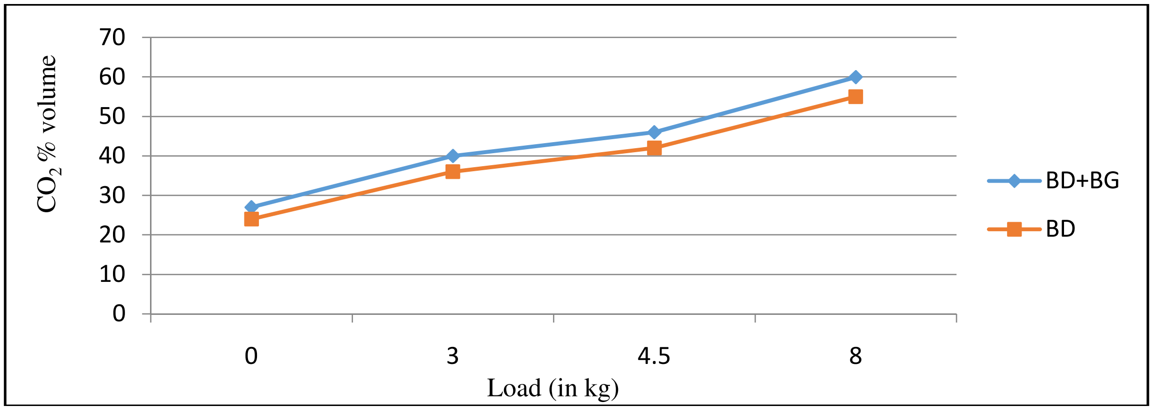

Figure 13: Variation of CO_2 emission

2.5. Exhaust Gas Temperature vs. Load

Figure 14 shows that the exhaust gas temperature increases with increase in load. The exhaust gas temperature of the biodiesel-biogas mixture in dual fuel mode is higher than the mono fuel mode because the energy supplied in dual fuel mode is higher than the energy supplied in mono fuel mode.

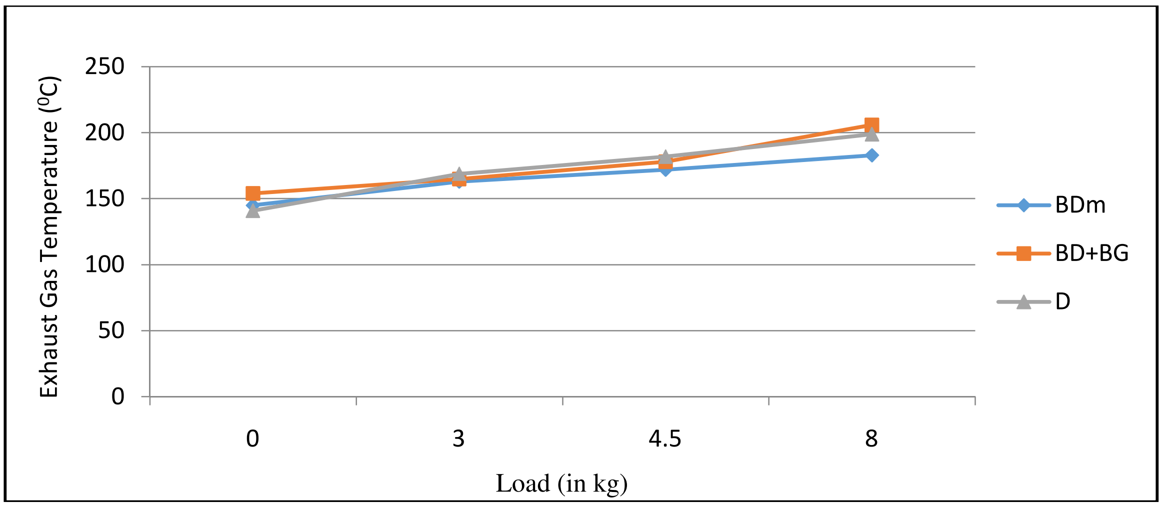

Figure 14: variation of exhaust gas temperature with load

3. Conclusion

This study was conducted to investigate alternate renewable source of energy in India their analysis on various performances and exhaust emission characteristics of dual-fuel combustion of biodiesel and biogas mixture and single fuel combustion of biodiesel in a single cylinder four stroke DI diesel engine under various load conditions. The following conclusions were drawn from the analysis:

1. Karanja oil biodiesel and biogas are easily accessible renewable source of energy in rural India which can be utilized in place of diesel in diesel fuel engine on duel fuel mode without any modification in engine.
2. The net energy consumption in dual fuel mode is more than the biodiesel consumption in mono fuel mode because of low energy content of biogas.
3. In dual fuel mode of operation proportional replacement of biodiesel is done by biogas which reduces consumption of biodiesel fuel.
4. Brake thermal efficiency of the biodiesel in mono fuel mode is greater than the biodiesel-biogas mixture dual fuel mode at all engine loads because of oxygen content in biodiesel which improve combustion better than biodiesel-biogas mixture. The CO_2 content of biogas in biodiesel-biogas mixture retards combustion in dual fuel mode.
5. At higher engine loads, the HC emissions were found to be reducing for dual fuel mode whereas the same was found to be slightly increasing for single fuel mode. The reason towards this can be stated as the higher octane rating of biogas results in faster rate of combustion in the combustion chamber at higher loads.
6. The CO_2 emission is more in case of dual fuel combustion mode as compared to single fuel biodiesel combustion; this is because of initial CO_2 content of the biogas fuel.

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