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Certain Investigations on the Performance of Emission, Vibration and Noise Characteristics of C.I Engine Using Bio Gas and Bio Diesel as Alternate Fuel

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Abstract: In recent times, there is an increase in air pollution and fossil fuel depletion are the major problems concerned. Automobile exhaust and industrial emissions are the two major factors which pollute the air. Diesel engines are widely used for heavy vehicles and in industries to generate electricity. The major problems in diesel engines are noise and vibration and it affects the human and plant life. Biogas can be produced from regionally available raw materials such as recycled waste, Biodiesel is produced from Jatropha oil it is environmentally friendly. Diesel engine is made to run with these fuels and diesel as a pilot fuel. The present work focuses on performance of engine, measuring the exhaust emissions, noise and vibration in different trials and at different compositions of fuels with the help of flue gas analyzer. Piezoelectric crystal sensor is used to measure the vibration in Hertz. The Noise is measured with the help of noise level meter. The range of measurement lies from 35dB to 140dB. Engine is made to run with base diesel, with different blends of biodiesel (B10, B20 andB30) and biogas. From this experimental study it has been concluded that, brake thermal efficiency of the engine is slightly reduced with bio-diesel blends and B20 & bio-gas mode compared to diesel. The emission like CO, CO_2, HC, smoke are slightly increased and HC, NO_x are slightly reduced when compared to diesel. The vibration and noise are reduced in bio-diesel, diesel blends but slightly increases in B20-biogas mode as compared to diesel.
Key Words: Bio Gas, Jatropha Oil, Vibration, Noise, Piezo Electric Crystal Sensor.

1. Introduction:

Economic growth of country is increasing day-by-day, along with this, transportation need is also increasing. This is mainly due to population and urbanization. But the fuel resources are decreasing gradually. To manage this demand for existing fuel it is important to consider the alternative fuel, which can be used as a substitute for the place of existing fuel. Research on renewable fuel “Biodiesel” is deemed to be essential in the present world. The term “biodiesel” commonly refers to fatty acid methyl or ethyl esters made from vegetable oils or else living thing those property be good quality adequately worn in diesel engines [1]. Biodiesel has been considered as an ideal alternative fuel for diesel fuel. Biodiesel is an environmental friendly fuel and has the potential to provide comparable engine performance results. Biogas and Natural gases can be the better substitute fuel for spark ignition (SI) and compression ignition (CI) engines [2, 3], because it can be used as fuel for car or to power city buses. Numerous research result data suggest that it is possible to increase the compression ratio as an effective means of improving performance of biogas fuelled engine when CO_2 is present in biogas [4, 5]. When bio-fuels are used, it releases only fractional amount of carbon in it emission [6], so that biogas has been variously used for heating purposes, electricity generation etc., [7, 8] and also it has been inferred that the using of biogas in engine improves engine efficiency due to complete combustion in the engine cylinder [9]. In modern fuel injection systems of reciprocate engines, non-identical container-wise torque input is a ordinary issue cause better torsion vibration level of the crankshaft and also stress of mechanical components. Each moving components of an engine usually produces a vibration signature on some points of the engine structure. Normally, the most important source of excitation that is likely to be observable from the vibration signal are associated with the following subjects:

1. Rocking and twisting of the engine block on its support, owing to the achievement of inner forces;
2. Impacts due to clearances at links, those at the crankshaft bearings and the so called piston slap being extremely noisy;
3. Closures and opening of valves;
4. High-pressure fuel injection in diesel engines;
5. Rapid rising of gas pressure in the cylinders during the combustion. Generally, noise may be controlled by reducing the excitation force applied to the engine body due to combustion process and also mechanical impacts. Moreover, noise may be controlled at source by re modifying the engine body so that (a) The body damps the forces applied to it due to combustion process and also mechanical impacts, with the minimum structural deflection (b) The panels and covers which radiate noise are isolated from body vibration or designated for minimum response to vibration excitation (c)The vibration energy in the normal mode is rapidly dissipated as heat by vibration damping treatments and (d) Designing a partial or full attachment [10,11].

2. Literature Review:

N.H.SRay et al reported that the engine performance test operating on biogas-diesel dual fuel in small diesel engine the brake thermal efficiency is decreased as the biogas percentage increase and reduction in CO and HC emission.

Violeta et. al Studied the impact of different biogas composition and exhaust gas recirculation(EGR) on the engine parameter where measured in the studies without EGR the NO_X concentration decrease was directly proportional to the concentration of methane in common fuel mixture.

Ravi et al, conclude that Emissions such as NO_X, Smoke and HC were found to be less for biogas with the temperature of 80°c. Increase in temperature of biogas reduces the emissions and improves the performance of the engine.

Satputaley et. al, measures have been adopted to overcome problems regarding contamination of moisture, H_2S, CO_2 etc., in the biogas by scrubbing it by using MEA, DEA, TEA or by using water with NaOH, CaOH.

Liaquat et.al reported that in engine exhaust gas emissions, there is a reduction in HC, CO and CO_2 were found for JB5, JB10 and J5W5 when compared to Diesel Fuel at both engine operating conditions. Whereas, NOx emission for all blend fuels was increased as compared to DF. However, J5W5 was found to be comparable with JB10 and produced better results except NOx.

Heidary et al reported that one of the important characteristics of diesel fuels is high noise and vibration. The magnitude of vibration acceleration in vertical axis was more than that in the other two axis and magnitude of vibration acceleration in the longitudinal axis was more than that in the side axis. Fuel blends have major effect on the vibration. It establishes that B100, B5 and B20 have the lowest vibration. On the different, B15 and B10 have the maximum vibration.

The literature review indicated that the research related to the single cylinder diesel engine vibration, noise and emission using blends of diesel-biodiesel and biogas has not been reported so far. Therefore, the objective of this study to conduct experiments on single cylinder direct injection diesel engine to measure vibration, noise and emission and explore the different diesel-biodiesel fuel blends and biogas.

3. Experimental Setup and Procedure

The experimental tests have been conducted in a single cylinder, four stroke, 3.7 kW direct injection in CI engine coupled with eddy existing dynamometer. The fuel be supplied to the engine from the diesel tank, located in the panel board. The burette was also placed in the same panel board. When the fuel clock is closed,

the fuel to the engine starts to flow from the burette and not from the fuel tank. Biogas is admitted to the engine at an air line, through gate valve and blower. The fuel flow rates were obtained by noting the time taken for

50cc of fuel utilization. The schematic diagram of experimental setup and instruments used for measuring the performance, emission, vibration and noise are shown in figure 1. The engine was started and allowed to warm-up for about 10 min. The engine was tested under six discrete part load conditions at 0%, 20%, 40%, 60%, 80% and 100%. For all conditions, engine speed was maintained constant at 1500 rpm. The time taken for 50cc fuel consumption was noted at each load for diesel, B10+D, B20+D, B30+D.

Table 1: Specifications of Instruments used for measuring the Emission, Smoke& Vibration

Gas analyzer	AVL 447 -Di gas analyzer
Smoke meter	AVL 437 Standard smoke meter
Blower type (RPM)	2800
Noise Meter	B&K (SL-2250)
Vibration	Piezoelectric sensor

Table-2 Fuel properties

S.NO	Fuel	Density	Viscosity @ 40°c	Flash point °c	Fire point °c	Calorific value KJ/ KJK
1	Diesel	0.838	3.20	54	56	42800
2	B10	0.842	3.26	60	64	42270
3	B20	0.849	3.69	64	69	42000
4	B30	0.858	3.79	68	73	41800

Table 3: Description of Fuels

S.No	Description	Abbreviation
1	Diesel	Diesel
2	Biodiesel of Jatropa with diesel	B10%,B20%,B30%
3	Biogas	BG

The table 1 shows the instruments used for measuring exhaust emissions, noise and vibration and the Table 2and Table 3 shows the fuel properties of Diesel, Biodiesel - Diesel blends

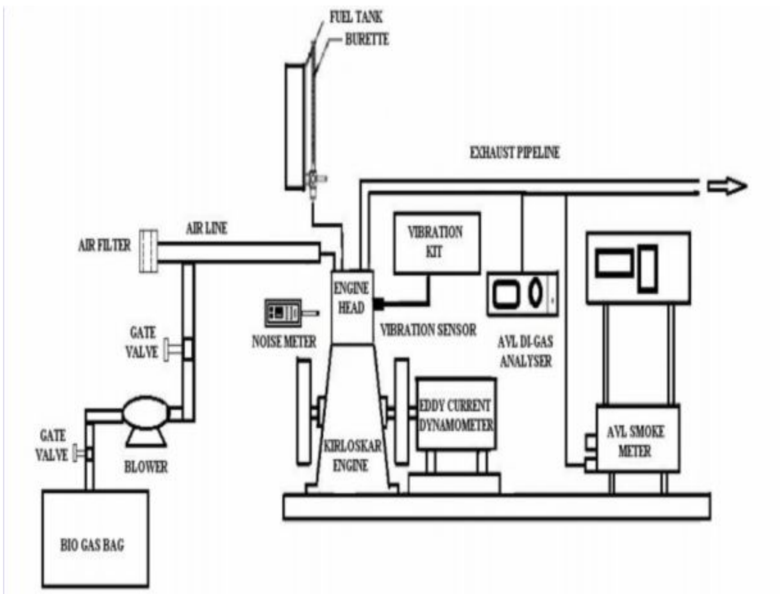


Figure 1. Experimental Setup

4. Result and Discussion:

A series of experiments have been conducted on a single cylinder four stroke diesel engine fueled with diesel, biodiesel blends, with diesel and biogas. The tests were carried out in standard injection timings (23ºBTDC). The important results of the experimental work are presented in the following sections. The configuration of different biodiesel blends and biogas with diesel is described in the table.

4.1. Performance And Emission Characteristics Of Bio Diesel Blends And Biogas:

4.1.1 Brake Thermal Efficiency:

The figure 2 shows the variation of brake thermal efficiency with brake power for Diesel, biodiesel-diesel blend and B20 blend with bio gas. The brake thermal efficiency indicates the ability of the combustion system to accept the experimental fuel and provides comparable means of assessing how efficiently the energy in the fuel can be converted into mechanical productivity. For the entire blends the brake thermal efficiency increases with brake power. Brake thermal efficiency is always found to be lower with increasing the bio diesel blends (B10, B20, B30) as compared with base Diesel this is because of the fuel properties such as higher viscosity, density and lower calorific value of bio-diesel blends as compared to diesel. When the bio gas and diesel are used as fuel, the brake thermal efficiency is further reduced compared to all bio diesel blends and B20 with bio gas the brake thermal efficiency is further reduced to lower value. This is because of lower energy content in the fuel mixture also bio gas has many impurities like CO_2,O_2,H_2S and other component limiting the combustion and mechanical durability of the engine(N.H.S.Ray,2014).

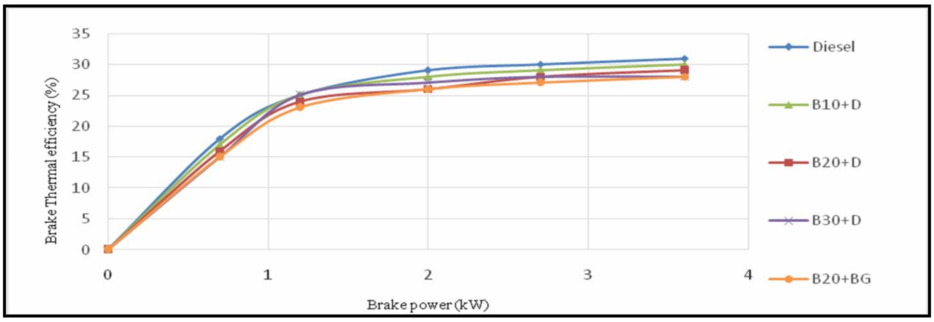


Figure 2. Brake Power Vs Brake Thermal Efficiency

4.1.2. Carbonmonoxide Emission:

The Figure 3 shows the variations of carbon monoxide in percentage of volume with brake power for Diesel, Biodiesel-diesel blends and B20 blends with biogas. CO is a transitional product of incomplete combustion of fuel. It is mainly dependent on the air-fuel ratio, relative to the chemical proportion increases. When the air-fuel ratio becomes greater than stoichiometric air-fuel requirement.

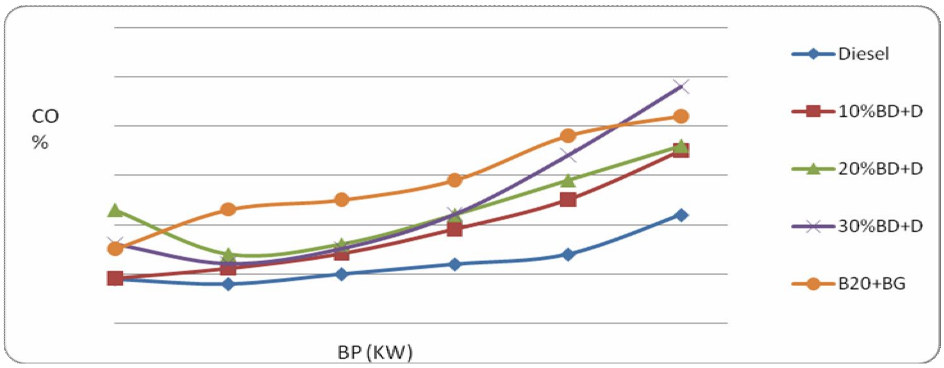


Figure 3. BP vs CO

At low loads (up to 30% load) the emission level of all fuels are similar. But in maximum load the emission of Biodiesel-diesel blends is slightly higher than that of diesel. This may be due to high viscosity and small increase in the specific gravity of the blended fuel reduce the consequence of fuel the spray pattern suppress the complete combustion. On the other hand, B20 with biogas as a fuel for operating the engine, the CO emission is higher than that of diesel. It indicate incomplete combustion, this may be due to minor species in the lean combustion and the mixture get richer the mole fraction of CO increases due to incomplete combustion (K.Vijayakumara reddy, 2013). The mixture of gas-air flow forced during the compression stroke of the engine reduces the amount of oxygen requires for complete combustion (S.H.Yoon, 2011). So it increases the CO.

4.1.3. Carbondioxide Emission:

The figure 4 shows the variation of carbon dioxide (CO_2) emission in percentage by volume with brake power for diesel, biodiesel- diesel blends and B20 blend with biogas. The CO_2 increases with an increase in brake power. All the blends (B10, B20 & B30) emits nearly same amount of CO_2 in comparison with diesel. In general bio-diesel is a low carbon fuel and has lower elements of carbon to hydrogen region than diesel fuel. All the CO_2 released during combustion has been separated from the atmosphere during the process of photosynthesis for the growth of vegetable oil crops, which are later processed into fuel. Hence, bio diesel also helps to mitigate global warming, as carbon dioxide levels are kept in balance.

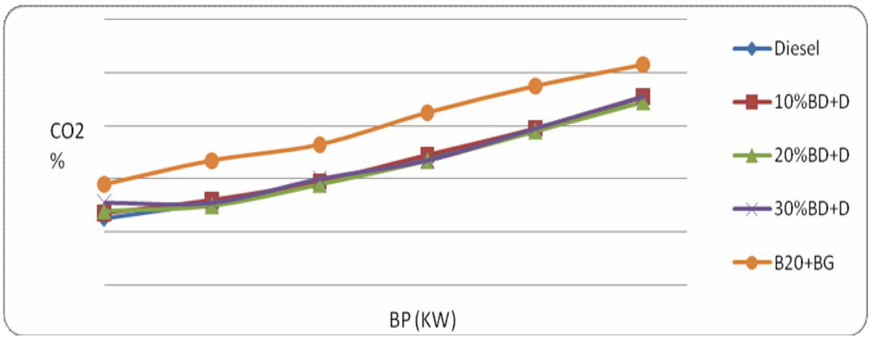


Figure 4. BP vs CO_2

On the other hand, B20 with biogas as a fuel for the engine be increased the CO_2 when compared to diesel. The biogas contains the mixture of CO and CO_2 i.e. (High carbon content compared to diesel). This is due to increase in CO_2 emissions.

4.1.4. Smoke Emission:

The figure 5 shows the variation of smoke capacity in percentage with brake power for diesel, bio-diesel, diesel blends and B20 blends with biogas for all the blends .The smoke capacity of the diesel engine exhaust is said to be a visible indicator of the combustion process. When compared to other harmful and invisible emissions. Smoke is more irritating and when it is cooled it cause nuisance. For all test fuel blends, the smoke emission increases with increase in brake power. The smoke emission increases with increase in blends ratio (B10 to B30) it is indicative of partial combustion. This may be due to increase in viscosity and low volatility of the blends (B10 to B30). This can result in poor mixture formation that leads to less fuel air mixing rates combined with large mean fuel spray droplet size.

In B20 with biogas operation, the smoke level is higher than diesel. This may be due to oxygen content in the biogas increases the gas flow rate it leads to increase the smoke emissions. [T.K.Kannan et al 2011].

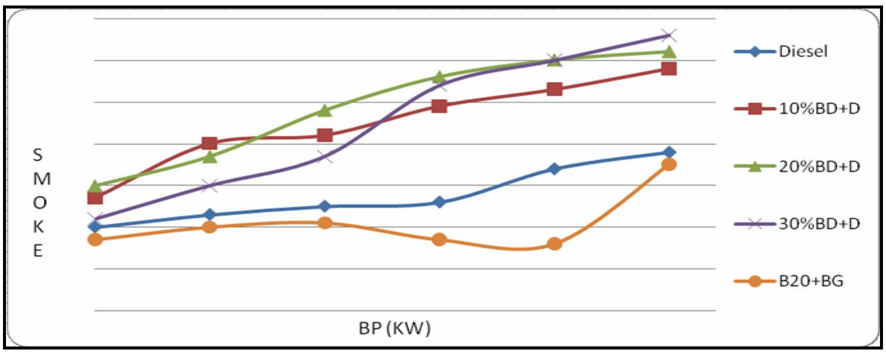
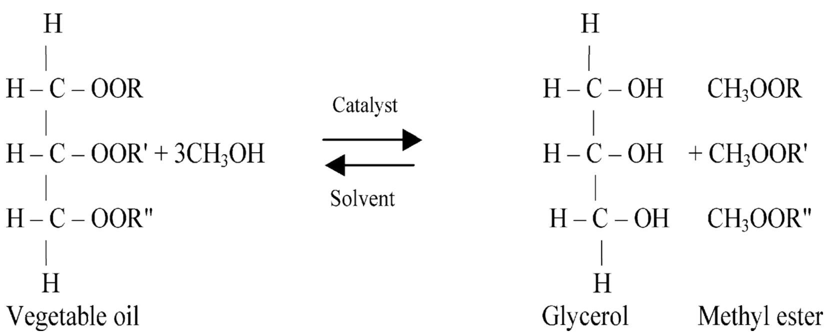


Figure 5. BP vs SMOKE

The smoke density is high in dual fuel mode compared with diesel. Smoke emission is high in biogas due to high oxygen content. In dual fuel mode operation, with increase in the gas flow rate, there is an increase in smoke density. This result is occurrence with previous researcher *A.S.Ramadhas,* (2011).

4.1.5. Hydrocarbons Emission:

Figure 6 shows the variations of unburnt hydrocarbons (HC) emission in parts per million (ppm) with brake power for bio diesel blends with diesel. For all the blends the amount of HC emission was lower in partial loads, but increases in higher loads. This is due to availability of relatively less oxygen for the reaction when more fuel is injected into the cylinder at higher loads. The HC emission of B20% is slightly decreased compared to B10% and B30% due to the effect of viscosity and density, which greatly influence the HC emission. The chemical reaction of the transesterification process is shown below



In B20 with biogas operation, the HC emission is increased when compared with diesel due to less time available for mixture formation during the combustion process since biogas has a longer burning rate. The high HC emission was also attributed to an unburnt charge, leaving the cylinder during the period of positive wide valve overlap of the diesel engine. Under light load conditions, the fuel is stripped the sprays during ignition delay and mixed with air beyond the lean limit of combustion. The mean temperature of the cylinder contents is so low and the flames are so localized that most of this fuel would simply be left unburnt. These results are occurrence with previous researcher *O.M.I.Nwafor*.

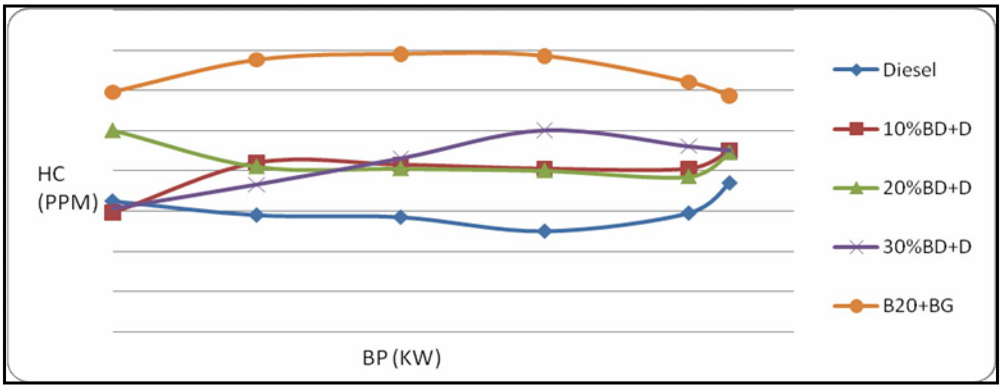


Figure 6. BP vs HC

4.1.6. Oxides of Nitrogen Emission:

The oxides of nitrogen in the exhaust emission contain nitric oxide (NO) and nitrogen dioxide (NO2). The formation of NOx is highly dependent on in-cylinder temperature, oxygen concentration in the cylinder. The figure 7 shows the variations of NOx in ppm with brake power for diesel, biodiesel-diesel blends and B20 blends with biogas.

The NO_x emission is lower for all blends of bio diesel due to less heating value than that of diesel. A short ignition delay period lowers the peak combustion temperature which suppresses NO_x formation. For the blends the NOx is reduced due to the low cylinder fuel temperature and cooling effects of methanol [Bio diesel]. In this NO_x emission graph, B20% value is slightly less compare than B10% and B30% at full load condition. That NO_x levels were lower with biodiesel operation at peak load condition when compared with diesel operation *[N.Venkateswara Rao et al-2013].*

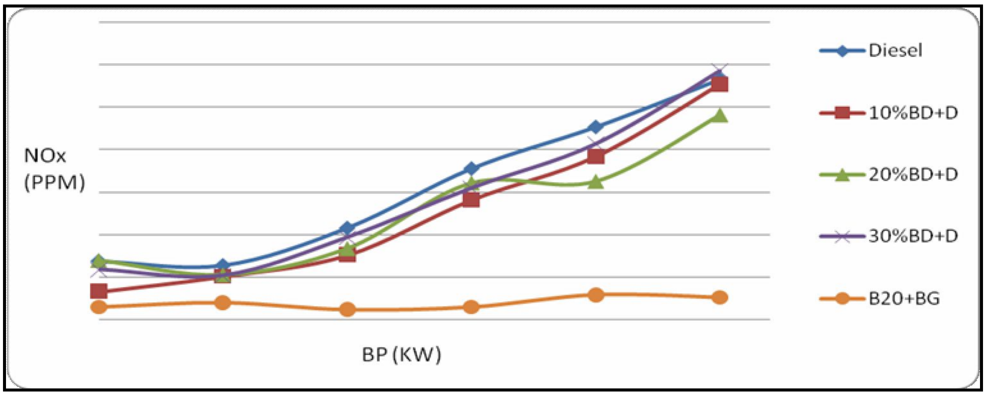


Figure 7. BP vs NO_x

In B20 with bio gas operation, the concentrations of NOx emissions were obviously lower at all engine loads, on an average, about 70% below the levels measured in single combustion modes. This was likely mainly due to the result of the lower rate of combustion of the gaseous fuel in the presence of CO_2 in biogas. The CO_2 of biogas dilute the oxygen concentration of the intake fluid. Moreover, the induction of biogas increases the specific heat capacity of the working fluid which there by caused the slowing of the flame propagation and the lowering of the combustion temperature during the combustion process compared to the single-fuel mode. Concurrently, the production of NOx emissions is suppressed with the combined effects of these phenomena in the case of biogas combustion. This result has occurred with previous researcher *Venkata Ramesh Mamilla (2011).*

The emission values of NOX are minimum for the biogas compared to diesel because it is a low calorific value fuel and it's a homogeneous mixture *(V.Gobinath, 2011).*

4.2. Vibration Comparision for Diesel, Biodiesel Blends, & Biogas:

4.2.1 Vibration Analysis

From the table 4 shows the measured values of vibrations produced from the engine operated at different blends of fuel. The instruments were placed nearer to the cylinder head of the engine.

It is clearly observed from the table, the engine operated with diesel mode, the vibration starts from 165hz to 206hz. Whereas in bio-diesel and diesel blends (B10 to B30) vibration declines (160HZ to 180 HZ), a compared to diesel as fuel. This may be due to the reduction in the knocking effect in the combustion behavior in bio-diesel, diesel blends. As a result of good combustion the vibration decreases at higher blends of biodiesel. This result is occurred with the previous researcher B.Heidary, S.R.Hassan-Beygi, 2013.

Table 4: Vibration Comparison in Hz

S.NO	Load	Diesel	Biodiesel			Biogas & B20
			B10	B20	B30	
1	0	165	160	170	165	170
2	20	170	172	172	170	157
3	40	179	176	169	168	166
4	60	180	178	169	169	184
5	80	184	167	179	169	180
6	100	206	180	172	162	184

In B20 with biogas operation at initial loading the gas flow is less and air mixture is high. Amount of oxygen should be more for good combustion. So vibration is less. (157Hz).

As load increases the gas flow is more to the engine which reduces the amount of oxygen required for complete combustion. *(V.Manieniyan and S.Sivaprakasam).*

At 100% load the vibration in biogas is reaches to 184Hz which is higher than biodiesel blends (180,172,162Hz) due to the knocking effect of the biogas at higher loads. At higher loads the air fuel mixture is uneven, this leads to incomplete combustion. The incomplete combustion produces more violent gas vibrations known as knocking.

4.2.2 Noise Analysis

From the table 5 shows the measured values of Noise produced from the engine operated at different blends of fuel. The instruments were placed nearer the cylinder head of the engine.

At 100% loading the noise is higher in diesel than, biodiesel. The diesel reaches to 98dB whereas the biodiesel is less compared to diesel. This is because, biodiesel always show lower peak pressure than mineral diesel and complete combustion nature of biodiesel than diesel.

At initial loading B10 has produced more noise (96.8dB) than diesel .as load is increased step by step it reduces below diesel

Similarly B20, B30 also produced least noise (97.1, 94.9dB) than diesel. B30 produced the least noise (94.9dB) because the biodiesel blend ratio increases the combustion takes place smoothly.

At 100% loading the Biogas produced little more noise than biodiesel because the Biogas contains 47% CO_2 in its composition. It affects the combustion process resulting in incomplete combustion which creates higher noise inside the combustion chamber than biodiesel.

Table 5: Noise Comparison in dB

S.NO	Load	Diesel	Biodiesel			Biogas & B20
			B10	B20	B30	
1	0	96.4	96.8	95.8	97.4	97.2
2	20	96.0	95.8	95.6	96.4	97.4
3	40	96.8	96.3	95.8	95.3	96.3
4	60	97.2	96.0	96.4	95.4	97.3
5	80	97.4	96.6	97.0	95.3	97.1
6	100	98	97.2	97.1	94.9	97.3

A number of origin of mechanically induced noise caused by various forces resulting from the combination of combustion gas and inertia forces which act on the moving parts of the engine to accelerate them across their running clearances and thus cause mechanical noise.

The noise and vibration can be varied based on the external factors. Background noise is also added while making noise measurement. Surrounding environment must be noise free to make an exact noise measurement from the engine.

5. Conclusion:

The following are the conclusions drawn from experimental results,

- The viscosity, density, flash point and fire point of the bio-diesel-diesel blends are slightly higher than the diesel similarly the calorific value of the bio-diesel-diesel blends are lower than the diesel.
- The brake thermal efficiency of the engine increase with increase in the brake power, when bio-diesel-diesel blends ratio increases with reduces the brake thermal efficiency compared to diesel, when bio-diesel, bio-gas mode the brake thermal efficiency of the engine reduces further, this may be due to quality of fuel.
- The emissions like CO, CO2, smoke are slightly higher than bio-diesel blends and bio-gas compared to base diesel.
- The value of NO_x and HC emission are reduced in bio-gas, bio-diesel blends compared to diesel. The noise and vibration of the engine operating on the bio-diesel, diesel blend is reduced, but in biogas, B20 mode the noise and vibration increased slightly because of air knocking effect of bio-gas.
- Up to 20% volume of the bio-diesel does not affect the performance of the engine.

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