Controlling Exhaust Emissions and Measuring Performance Values from a DI Diesel Engine Using Substitute Fuel

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Abstract

In addition to being a major worry for a nation's financial development, the rising consumption of petroleum products caused by an increase in the number of automobiles also contributes to environmental damage. The large, antiquated agricultural cooperatives that help put power back in the hands of the people gave rise to biodiesel and ethanol cooperatives. Alternative fuels are frequently produced domestically, making use of a nation's resources and boosting its economy. In the current study, bio-diesel made from jatropha oil has been used to cut down on diesel fuel use and clean the environment. On the single cylinder direct injection diesel engine of the Kirloskar AV1, fuel samples comprising 20 percent, 40 percent, 60 percent, and 80 percent mixes of Jatropha biodiesel with diesel have been evaluated. The features of exhaust emissions and engine performance have both been researched and assessed. Around 20% of diesel and jatropha biodiesel is reported to operate well in engines. When the load increases up to 80% of the maximum engine load, carbon monoxide and unburned hydrocarbon emissions are observed to be reduced, and when the load is increased further, the emissions are observed to be increased. In contrast, nitrogen oxide emissions slightly increase as the engine load increases on the engine up to 80% of the maximum engine load; however, after that point, they continue to decrease because biofuel contains oxygen.

Keywords: *Alternative fuels, Blend of Bio-diesel, Emission Characteristics, Performance, Environment Safety*

Introduction

In the contemporary era, biodiesel is an important alternative fuel for diesel engines. Vegetable oil-derived biodiesel has superior performance and lower emission characteristics. We are looking for an alternative fuel because of the rising need for fuels in transportation and other industries, as well as the risks they pose to the environment. For improved performance and a pollution-free environment, vegetable oils were utilized in diesel engines. They also restored the petroleum diesel that had been studied in the previous century. Over the years, numerous scientists and researchers have investigated the use of various vegetable oils in diesel engines. However, some physical-chemical characteristics of vegetable oils, such as their high viscosity, low volatility, and tendency to create carbon deposits, tend to limit their usage as fuel in DI Diesel engines. Through experimental research, it was determined and widely acknowledged that the transesterification process is a reliable way to prepare biodiesel and lower the density and viscosity of vegetable oils. Transesterification techniques involve a reversible reaction

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between the triglycerides in vegetable oil and alcohol in the presence of an acid or base as a catalyst. The monoalkyl esters of the vegetable oil start to develop right away during transesterification, and glycerine is created as a by-product of the procedure. Biodiesel is the common name for the monoalkyl or methyl esters of vegetable oil created during transesterification. India is making an effort to produce methyl esters or biodiesel utilising non-edible and underutilised oils [1]. The simplest way for producing biodiesel, according to a number of research, is to transesterification crude vegetable oil with alcohol in the presence of a catalyst [2]. At various engine loads, fuel blends of 20 percent, 40 percent, 60 percent, 80 percent jatropha biodiesel with diesel and 100 percent jatropha biodiesel blends were examined. We measured the brake thermal efficiency (BTE), specific fuel consumption, and carbon dioxide, carbon monoxide, hydrocarbons, and NOx emissions from the exhaust. The engine's default settings for using diesel oil are maintained. A lot of attention has been paid to biodiesel as an alternative fuel, which is produced by transesterification of Jatropha seed oil with single fuel.

An investigation was conducted using clean Jatropha oil in a single-cylinder, constant-speed, direct-injection diesel engine. By altering the injector timing, injector opening pressure, injection rate, and air swirl level, several characteristics, including performance, emissions, and combustion, are investigated. The BTE is observed to have increased from 25.7 to 27.3 percent, but the HC and smoke emissions levels have decreased from 3.9 to 3.3 BSU. Additionally, the level of NOx has increased.In addition, it was mentioned that, under some circumstances, the ignition delay with Jatropha oil is always longer than with diesel engines, moving the injection timing from the base diesel value. The performance and emissions have shown a slight improvement despite the delayed injection timing. The swirl barely influences emissions [3].

In one experiment, a single-cylinder compression-ignition engine running on biodiesel derived from jatropha oil (abbreviated JBD) was used. When the engine was running with warm EGR levels at 5.25 percent, the NOx was seen to have decreased. It also demonstrates a sufficient reduction in NO emissions, as well as a reduction in potential smoke, CO, and HC emissions, and a respectable braking thermal efficiency. When compared to diesel, JBD emits less smoke at higher loads while producing more smoke at lower loads [4]. Three different biodiesels, namely karanja, putranjiva, and jatropha, were compared in terms of their fuel qualities, performance, and emission characteristics. The Riscardo Variable Compression Engine was the subject of the tests, which determined which was optimal for use with diesel engines. It was determined that blends of jatropha and B100 karanja had greater efficacy. When compared to other biofuel blends, jatropha exhibits the greatest reduction in emissions and fuel efficiency. The findings demonstrated that jatropha outperformed substitutes like putranjiva and karanja in terms of fuel characteristics, performance, and emissions [5].

A research was carried in a 7.5 KVA diesel engine generator with the biodiesel produced from raw jatropha and karanja oil and blends with diesel to generate power [6]. The generator showed a improved overall efficiency for 6000 W loading conditions when used jatropha and karanja oil as blend. The overall efficiency was improved at a range of 31-33% and 33-39% respectively. A comparison thereby made on diesel fuel generator with pure biodiesel of karanja and bio diesel blends B80 resulted in more power & overall efficiency. The overall efficiency on jatropha bio diesel blended fuel is found to be less than that of diesel fueled generator. An experiment on diesel engine to carry out the combustion analysis of jatropha, karanja and polanga based biodiesel as a fuel in a diesel engine. This investigation is blindly focused on biodiesel in a single cylinder diesel engine used for horticulture applications in India. The engine combustion criteria such as ignition delay, peak pressure and its time of occurrence, heat release rate were measured by conducting combustion tests at varying loads(0%,5% & 100%) using neat biodiesel from jatropha, karanja and polanga and their blends (20% & 50% by volume). The result showed that the ignition delay has been persistently shorter for neat jatropha biodiesel, by varying the crank angle between 5.9^o to 4.2^o with increasing the load. Polanga biodiesel is found to be the most favorable fuel blend as it results in maximum peak cylinder pressure. In the same way the ignition delays are found to be shorter for neat karanja and polanga biodiesel when compared diesel [7].

The preparation of biodiesel (Neem Oil), which is a mono ester made by the transesterification method, is anticipated to take into account the issue of the supply of neem seeds. A safe alternative to traditional petroleum diesel is biodiesel [8].It has maximum lubricity, and is a clean burning fuel and can be a fuel component for use in existing unmodified diesel engine. After getting the final sample, the pH value of oil is checked and found to be 5.6 which mean it is acidic then as a catalyst NaOH is added with few drops of HCL and it showed a pH value of 7. Identification of Flash and Fire point and Viscosity index were also observed. The engine power and pollutant emission characteristics under different biodiesel percentages were also studied. Experiments demonstrated that in the single cylinder diesel engine the biodiesel produced using neem oil could reduce Smoke and Carbon monoxide emissions, extensively while the NOx emission changed a little. Thus, the ester of this oil can be used as ecofriendly substitute fuel for (C I) diesel engine.

A four-cylinder engine experiment using jatropha biodiesel at percentages of 5, 10, 15, and 20 was used for an analysis of engine performance and emission characteristics, along with antioxidants N, N'-diphenyl-1 and 4-phenylenediamine [9]. The engine was put through testing with a speed range of 1000-4000 rpm at an interval of 500 rpm when it was operating at full throttle. The findings indicated that adding antioxidant to jatropha biodiesel lowers NOx emissions but has little effect on CO, HC, or BSFC [Brake Specific Fuel Consumption] or engine power. When DPPD additive is introduced, the CO and HC emissions are either reduced or roughly the same as those produced by diesel combustion.In comparison to biodiesel blends without the additive under full throttle, the addition of 0.15 percent (m) DPPD additive to jatropha blends of 5, 10, 15, and 20 percentage revealed reduced NOx emissions of 8.03 %, 3.5 %, 13.65 %, and 16.54 %, respectively.

The palm biodiesel and jatropha biodiesel obtained from crude vegetable oils through transesterification process and it was used in diesel engine. The properties of the produced biodiesel have been presented and found that it is up to ASTM standard of bio diesel specification. The mixed palm and jatropha blends were tested in a single cylinder diesel engine at various engine speeds ranging from 1400 to 2200 rpm. This study showed a slight increase in BSFC compared to diesel, while at the same time all tested emission parameters, including noise emission and CO, were substantially decreased. When compared to sole fuel, it was calculated that the CO, HC, and sound levels from palm and jatropha biofuel blends were lower in proportion [10]. This was attributed to damping, which results in instantaneous failures and lubricity. Analyzing the exhaust emissions through an inquiry of a compressed ignition engine. First, the production method and attributes are examined and evaluated against three biodiesels, including calophyllum inophyllum, ceiba pentandra, and jatropha curcas [11].

Then the performance of the diesel engine and the exhaust emissions testing were made on bio diesel blends of 10%, 20%, 30% and 50% at full throttle load. It was identified that 10% bio diesel blend produces the best results of engine torque, engine power, fuel consumption and brake thermal efficiency among all the blends. The blends show a slight increase in NOx and with a slight reduction in CO_2, CO and Smoke opacity. The engine performance and emissions produced from Rice Bran Oil Methyl Ester blended with neat diesel fuel in various volumes was investigated. The biodiesel production process and properties are discussed. Pure rice bran oil of 10%, 20%, 30% [B10, B20, B30] biodiesel blends are mixed with diesel fuel. The experimentation were conducted in a four stroke single cylinder direct injection water cooled diesel engine equipped with eddy current dynamometer without varying the constant speed and at full load condition. The performance criteria's such as brake power, torque, specific fuel consumption and brake thermal efficiency were measured for diesel and all blended fuels of B10, B20, B30 respectively. The result shows that the brake power of the engine using the blends is very close to the value obtained with diesel. A nominal reduction in brake power is obtained with B30 blend. A nominal reduction in brake power is obtained with the B30 blend. The BTE of the test engine for the three blends was found little lower than the value obtained with diesel. The engine with B30 blend shows 3.4% reduction in BTE. The BSFC increases linearly with the increase in biodiesel percentage in the various blends. Around 5% increase in BSFC is observed with the B30 blend. As per the exhaust emissions with the blends, it was found that the CO, HC and smoke emissions were reduced significantly when compared to those of diesel. The results show around 50% reduction in smoke, 34% reduction in HC and 38% reduction in CO emissions at maximum load conditions. It has been determined that the test

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engine's operation with RBOME mixes produced extremely satisfactory performance. The exhaust emissions of CO, HC, and smoke significantly improved while the engine was running with the various mixes, and it is quite similar to that of diesel oil. This study comes to the conclusion that biodiesel blends can be used as a fuel substitute in diesel engines without requiring any engine modifications [12]. To determine the combustion parameters, a 10.3 KW single cylinder, four-stroke, water-cooled direct injection (DI) diesel engine was evaluated using an emulsified fuel that contained 10% and 15% water by volume made from a diesel blend with 10% jatropha biodiesel [13].The experiments were conducted to determine the hydrophilic-lipophilic balance (HLB) which is by calculating the values for the different regions of the molecule. It resulted that JB10 and emulsified fuel exhibits similar combustion stages as like diesel with no increase in percentage of water, the ignitions delay has been found to be get increased at higher engine loads. Emulsified biodiesel can be recommended in place of biodiesel as they emit CO, CO_2, HC & NOx at a very negligible ratio.

An impact of oxygenated additives to palm and Jatropha biodiesel blends to frame the performance and emission characteristics of a light duty diesel engine was studied [14]. An investigation was made to improve the blend of these two biodiesels P20 & J20 [20% biodiesel blend] with the help of oxygenated additives. The comparative improvement of P20 & J20 blends with ethanol, n-butanol (or) diethyl ether as additives has been assessed in terms of performance and emission characteristics of a four stroke single cylinder diesel engine. Tests were carried at different speeds of 1200 to 2400 rpm without varying the full load condition, using the blend which finally consists of 80% diesel, 15% biodiesel and 5% additive. The test resulted that the use of additives improves the brake power and brake thermal efficiency (BTE). At 2200 rpm the use of diethyl ether has increased brake power and brake thermal efficiency at a rate of 4.10 & 4.4 % respectively when compared with P20 blend. The same improvement was noted for J20. Performance has also improved for other two additives also. Even if HC emission is increased slightly, all blends with additives have minimized NOx and CO emissions than P20 & J20 virtually all over the entire engine test. The emissions of NOx were reduced to 13% when diethyl ether added as additive and in the same way the CO emission has reduced by 40 % while ethanol is added as an additive. The blends emission characteristics were controlled by additives like oxygen content, volatility and latent evaporation heat etc. This experiment expose the potential important of palm and Jatropha biodiesel blends with the addition of three promising additives. The main focus is on the performance and emission strategy while using biofuel (Coconut oil) as a substitute in diesel engine. An experimental arrangement is used to study the performance of a small diesel engine using different blends of biodiesel converted from coconut oil. With biodiesel, the engine is proficient running without difficulty. Different blends of biodiesel (i.e. B75, B50, and B25) have been used to avoid problematical modification of the engine or the fuel supply system [15]. It is concluded that a comparison of engine

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performance for different blends of biodiesel has been accepted to determine the best possible blend for different operating conditions and coconut oil–diesel fuel blend resulted in lower smoke and NOx emissions. Moreover the concentrations of biofuel increase the emissions of carbonyl compounds and that of acetaldehyde when compared with results from sole fuel (diesel) with same engine. The reduction of CO and HC is due to the oxygenated fuel of biodiesel. NOx emission increased with increase of percentage ratio of biodiesel. The increase of NOx emission due to the higher cetane number of biodiesel will reduce the ignition delay. The use of exhaust gas recirculation (EGR) can also reduce the NOx emission where the temperature of exhaust gas is reduced when passing through the combustion chamber. Possible impacts of changing diesel to B75 diesel indicate an increase of ozone formation. In terms of environment health, a lower impact was projected considering only the changes in biofuels concentrations. Make use of biofuels as Internal Combustion engine fuels can participated a very vital role in helping the developed and developing countries like India to reduce the environmental collision of fossil fuels. Researcher concludes overall to make the atmosphere is greener; it was use bio-diesel [16].

At various engine speeds and with the engine running at 75% load, tests were conducted. The largest reductions in thermal efficiency for B100 compared to diesel oil at 75% of engine load were 33%, while the maximum reductions in output braking power and volumetric efficiency for B100 were 27 and 9%, respectively. The B100 experienced a 47 percent rise in NOX emissions at 75 percent engine load when using diesel fuel. For B100, the largest reduction in smoke emissions was 22% when the engine was running at 75% of its maximum load. Blends of biodiesel had lower cylinder pressures and heat release rates than straight diesel. Screw press oil extraction was chosen as a biodiesel feedstock due to its better physical and chemical characteristics [17].

Biofuel Blends

Biodiesel and its blends have been prepared by various amount of biofuel with diesel. The properties of biofuel blends have been measured and noted in Table 1.

Table 1 - Properties of Diesel and Biofuel Blends

Blends	Diesel	B20	B40	B60	B80	B100
Density, kg/m^3	812	831	846	851	860	872
Kinematic Viscosity at 40^oC, mm^2/sec	2.83	3.91	4.93	5.87	6.78	8.74
Calorific Value, MJ/kg	43.73	42.76	40.36	39.87	39.02	37.85
Flash Point, ^oC	49	74	85	97	112	147

The blends were designated by “B”. For example, B20 indicates that it contains 20% of biofuel (Jatropha biodiesel) and remaining 80% is diesel, B40 indicates that it contains 40% of biofuel (Jatropha biodiesel) and remaining 60% is diesel, B60 indicates that it contains 60% of biofuel (Jatropha biodiesel)

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and remaining 40% is diesel, B80 indicates that it contains 80% of biofuel (Jatropha biodiesel) and remaining 20% is diesel, B100 indicates that it contains only biodiesel ((Jatropha biodiesel). For finding the optimum ratio, the blends B20, B40, B60, B80 and B100 were prepared. Experiments have been conducted based on above mentioned blends.

Experimental Set-Up & Procedure

Figure. 1 - Experimentation - Engine Set-up

A single cylinder, four stroke, water cooled diesel engine was used in this investigational study. The schematic representation of the experimental setup is as shown in figure 1.

The specification of the diesel engine used in the present work is given below.

Specification of Test Engine

Engine type	: Kirloskar AV 1 engine
No. of Cylinder	: Single Cylinder
Cooling Method	: Water-Cooled,
Cubic Capacity	: 0.553(ltr)
Method of ignition	: CI Diesel Engine
Cylinder Diameter	: 80 mm
Piston Stroke	: 110 mm
Engine Weight	: 130 kg
Compression ratio	: 16.5: 1
Loading device	: Eddy Current Dynamometer
Rated Output	: 5.1 kW

An experiment was conducted in a single cylinder diesel engine. Experimentation was carried out from no load condition to full load at the interval of 20% load. Load variations were done using an electric dynamometer. Engine maximum speed 1500 rpm was noted from the standard specification template. The flow metering system consists of a glass burette and a stop watch to calculate the volume flow rate of diesel. The engine has been tested with base fuel and different fuel blends (B20, B40, B60, B80 and B100). Exhaust gas emissions were measured using Indus 5 gas analyzer and smoke meter. In each test the volume flow rate of diesel and the constituents of exhaust emission such as CO, NOx, HC and smoke density were measured at steady states. Each test was repeated with the usage of biofuel blends and the values are measured. It was taken for evaluation of engine performance and emission characteristics.

Results and Discussion

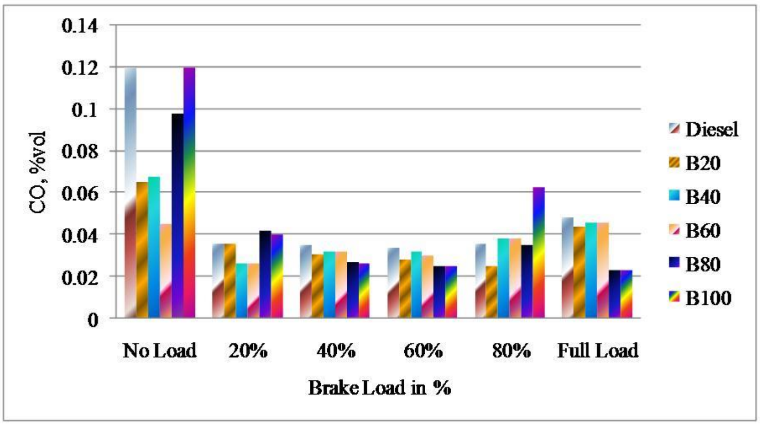

Figure. 2 - Variation of carbon monoxide emission with brake power

Figure 2 shows the variation of carbon monoxide (CO) with brake load for different blends of biofuel and diesel in the test engine. It was observed that CO reduces in engine exhaust as load increases up to 60% of rated load, after that CO increase in different blends. CO was increased, because of incomplete combustion in raising range of load. As the biofuel content increases in fuel samples, it reduces up to B20, and then it was increases and decreases.

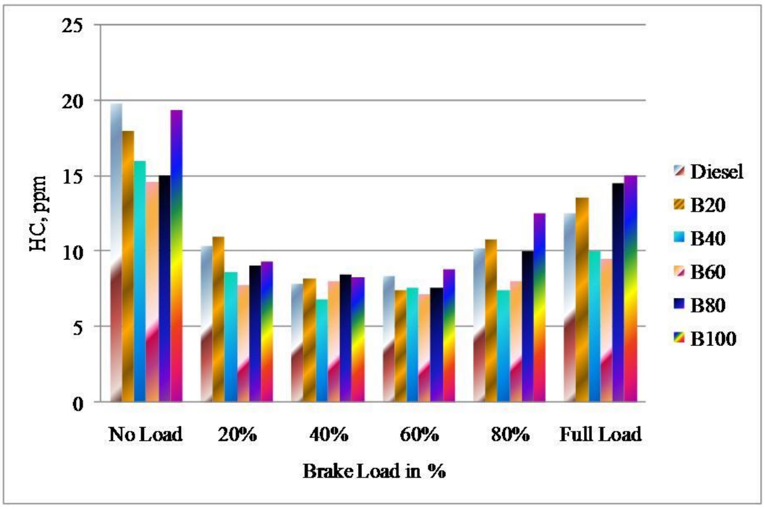

Figure. 3 - Variation of hydrocarbon emission with brake power

Variations of un-burnt hydrocarbon in exhaust gas with brake load for different blends of biofuel and diesel in the test engine shown in figure 3. HC values were observed that for all the blended fuel

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tested on engine, un-burnt hydrocarbon reduces with increase of load up to 40% of engine load and, after that it gradually increases. It may be occur due to poor combustion at peak load. As biofuel content increases in fuel sample, it reduces upto B60, after that it increases.

Figure 4 shows the values in oxides of nitrogen (NOx) present in the exhaust gas. The NOx values were observed at different loads, that when there is an increase in the load, the brake load also gets increased upto 60% further more it reduces for most of the blends tested. It may be because of improper combustion at higher load due to calorific value and viscosity of fuel. The maximum concentration of NOx has been found to be 491°C for B20 and B80 blend at 80% of rated load.

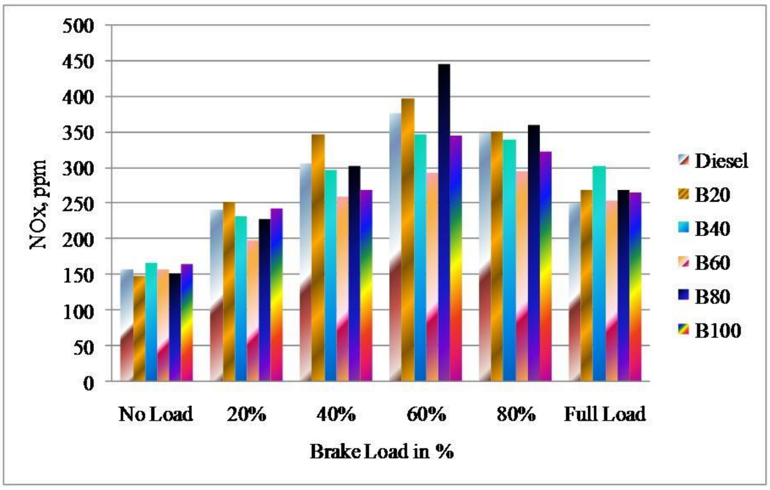

Figure. 4 - Variation of oxides of nitrogen emission with brake power

Smoke density values were observed and plotted a graph as shown in figure 5. It is identified that there was an increase in smoke density when the brake load is increased for different fuel blends. Main reason for this kind of activity was incomplete combustion of fuel at all loads. The smoke percentage in exhaust has been found to be 56HSU at full load for B20 fuel which is 11.11% lower than diesel. Combustion improves based on the availability of oxygen molecules present in biofuel blends.

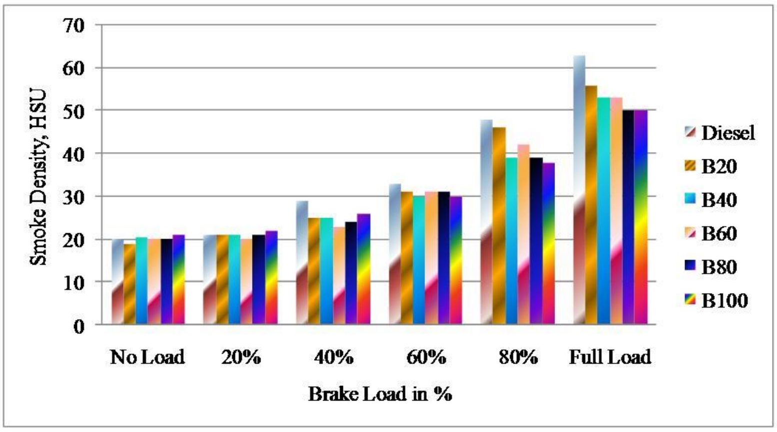

Fig. 5 - Variation of smoke density with brake power

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Brake thermal efficiency of the test engine was calculated from the observed data, while the engine was fueled with diesel and biofuel blends as shown in figure 6. When the engine load varies from no load to maximum load, BTE for all tested fuel blends also increases. Minimal amount of energy input shows on maximum raising level of break power developed, with an increase in break load of the engine.

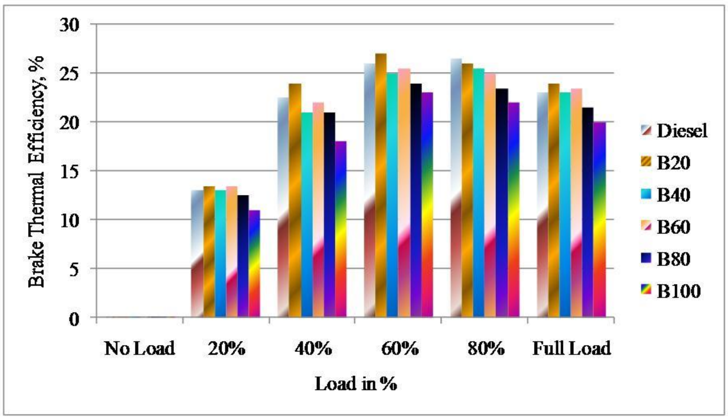

Figure. 6 - Variation of brake thermal efficiency with brake power

When the efficiency of the engine is at 80% load fueled with diesel is slightly lower than B20 blend fuel sample. While mixing the jatropha biofuel in sole fuel (diesel), the BTE of experimented engine is improved. Jatropha biofuel offers best lubricity to the fuel loss of power in the fuel pump. Biodiesel boosts the combustion quality due to heavy amount of oxygen molecules present in it. Pure biofuel is involved in this research, which shows lower value of BTE in all loads compared with diesel fuel. After the final observation, biofuel blend B20 presents better than sole fuel (Diesel).

Fig. 7 shows variation of BSFC with brake load for sole fuel and biofuel blends. In reality when the engine load increases; the brake power also increases for better consumption of fuel injected in engine cylinder. Based on that, this experimentation result show a decrease in BSFC value with a increase in the engine load for all the biofuel blends tested on the engine till 80% of the rated load, than that it further increases.

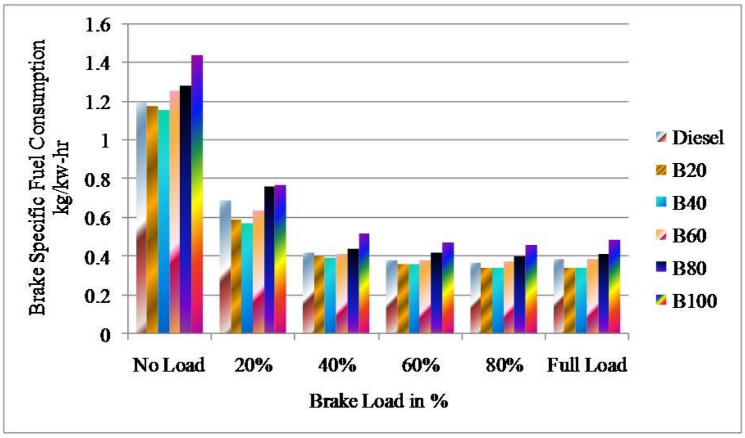

Figure. 7 - Variation of brake specific fuel consumption with brake power

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The increase in fuel consumption resulting in lower BSFC was more compared with the increase in brake power. As biofuel blend in B20 the BSFC values of the engine is lower than that of diesel for every load. In case of fuel blend more than B20, BSFC values are higher than that of sole fuel. Hence it was found that a larger amount of biodiesel is supplied to the engine compared to diesel. Variant of exhaust gas temperature with brake load for different blends of bio-diesel and diesel in experimented engine was shown in figure 8.

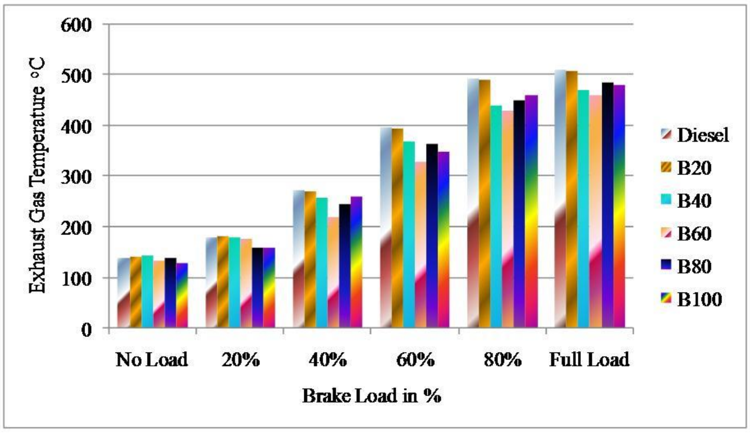

Figure. 8 - Variation of exhaust gas temperature with brake power

It is observed that EGT of biofuel blends are found to be lower than the diesel for all loads. The EGT of diesel at rated load is 510°C where as for jatropha biodiesel, it is 481°C. Again data's were observed that EGT increases with the increase in engine load for the different blended fuel tested. EGT of B20 has been found almost equal to diesel in all the loads. The maximum EGT has been found as 510°C for diesel and 508°C for B10 at full load. While biofuel blends increases the exhaust gas temperature value reduces. It may be occurred in biofuel blends due to the reducing trend of calorific value. The maximum amount of temperature is observed due to the oxidation of unburnt hydrocarbon in exhaust pipe.

Conclusion

Alternative fuels typically result in lower car emissions, which in turn result in less smog, air pollution, and climate change. The majority of diesel engines create harmful pollutants such carbon monoxide, nitrogen oxide, hydrocarbons, and many others.

- Jatropha biodiesel was therefore accepted as an alternate fuel to replace single fuel without changing the diesel engine.
- Additionally, emission tests were also carried out based on the characterization of bio diesel, which is the single fuel and contains all the significant features. These tests show that Jatropha biodiesel in diesel engines replaces diesel fuel in the engines partially or completely without altering the engine system.

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- The results showed that the best distribution for brake thermal efficiency and break-specific fuel consumption was found to be 20% and 40% of Jatropha biodiesel with sole fuel.
- On the spectrum of brake power, NOx emission is found to be slightly higher than other blends, however some engine emissions, such as unburned hydro carbon, carbon monoxide, and smoke opacity, show a substantial reduction.

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