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Improvement in the Environment Health and Engine Performance on Diesel Engine using Biofuel as a Substitute

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Keywords: Biofuel, Diesel Engine, Emission Control, Environment Safety, Performance Analysis

ABSTRACT

This experimentation focuses on the diesel engine performance and emission characteristics using coconut biodiesel blends without any engine alterations. The fuel properties of diesel and biofuel blends are analyzed. The engine is capable of running without difficulty in biodiesel mode. Engine performance test interval is 200 rpm. And, emission tests have been carried out at maximum speed at 100%, 90% and 80% throttle position. Outcome of this experimentation showed that fall in brake power, while rise in specific fuel consumption has been identified for biodiesel over the entire speed range compared to sole fuel (diesel). In case of engine exhaust gas emissions, raising CO_2 and diminishing HC, CO, Smoke Density and increasing of NOx emissions have been identified for biodiesel compared to diesel. Thus has been carried out at full load, keeping throttle 100% wide open with variable speeds at an, it can be concluded that BD1,BD2 and BD3 can be used in diesel engines without any engine modifications and have positive special effects both in terms of exhaust emission reductions and engine performance. This article pointed out that biofuel has potential to reduce greenhouse gas emission for more than 80%; which most of the developed countries have put their target and authorization to use biofuel.

INTRODUCTION

In the world of development, lot of theories and experimentations was focusing in present plan to finish world economic condition and encourage growth. Main approach is to develop sustainable industries through non-public sector development to encourage entrepreneurship gross domestic product growth and employment generation. The chance of developing a biofuel industry in world would ensure the creation of those factors within the geographical region, decreasing the economic condition that afflicts thousands of subsistence farmers whereas providing renewable sources of energies for the country (Kanthavelkumaran et al., 2013). A requirement of bio fuel is an important crisis at present scenario. Fuel and energy crunch and the concern of the society for the depleting world's non-renewable energy resources led to a renewed interest in the quest for substitute fuels. A most promising alternatives fuel is the vegetable oils and their products. A main use of vegetable oil in a compression ignition engine was first demonstrated through Rudolph Diesel who used peanut oil in his diesel engine. The need for fossil fuel is constantly increasing world over causing in rapid reduction of fossil fuel deposits (Tesfa et al., 2012). In lot of research studies and funded projects, this was experimentally inspected that the human health hazards are connected with exposure to diesel engine exhaust emissions like CO, CO_2, HC, NO_x and smoke density (Iwai et al., 2000; Dybdahl et al,., 2004). Thus, partial fossil fuels and supported environment pollution, it has become a universal issue to develop such kind of clean fuel, which is domestically available, technically feasible and environmentally suitable (Liaquat et al, 2010). Some methodology focused that coconut oil and its blend with diesel fuel gives higher BSFC than diesel fuel and worse emissions because poor atomization due to high viscosity and heating value of coconut oil is lower than diesel fuel. High viscosity of coconut oil impacts on better fuel system components lubrication. On the other hand, engine oil degradation is greater when operate diesel engine with coconut oil. So, it reduces period of engine oil (Iman et al., 2009).

In observation of the current insecurity in oil price level, biofuels stands as a smart source of substitute

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energy source. Although increasing the use of biodiesel, worldwide countries have reduced from over-dependence on crude oil reserves (Alamu et al., 2007). In connection that fossil fuel has been reported as being fixed. However it is admirable to note that biodiesel will not completely displace liquid fuels and its products, biofuel will takes its place as an alternative fuel and can be a source of lubricity as an additive to diesel fuel. Biodiesel is an oxygenated, renewable, decomposable and environmentally friendly bio-fuel with low emission profile (Hirkude et al., 2012). Number of researchers were concentrated their works and found that biodiesel fuelled engine created minimal loss in engine torque and power & increases their BSFC as compared to diesel fuel. Moreover that, it reduces the emissions of carbon monoxide (CO), hydrocarbon (HC), sulfur dioxide (SO_2), polycyclic aromatic hydrocarbons (PAH), nitric polycyclic aromatic hydrocarbons (nPAH) and soot (particulate matter). On the other hand, a majority of research output have showed an increase in oxides of nitrogen (NOx) (Aydin et al., 2012; Carraretto et al., 2011). In addition, with pure biofuel, the maximum torque was found to have extended at higher engine speed. Exactly the same outputs were identified by Aydin and Bayindir (2010) using cottonseed oil methyl ester. However, a decrease of CO, NOx and SO_2 emissions were observed in the similar research.

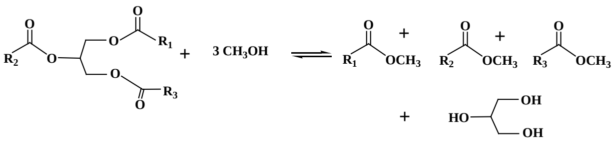
In another research (Ghobadian et al, 2009), similar power and torque output with higher BSFC were recorded using waste cooking biodiesel when compare to diesel fuel, whereas in terms of exhaust emissions, lower CO and HC emissions were reported. The main purpose of the present investigation is to determine the fitness of using BD1, BD2 and BD3 on CI engine without any major modification. Then the results of these blend fuels with diesel fuel is compared in terms of engine performance, exhaust emission (HC, CO, CO_2, NO_x soot and sound level.

BIO FUEL STRATEGY

Mainly biofuel is derived from vegetable oils. Major component in vegetable oil is triglycerides. Triglycerides are esters of glycerol with long chain fatty acids, commonly called fatty acids. Bio-diesel is defined as mono alkyl esters of long chain fatty acids from renewable feed stock such as vegetable oil or, animal fats, for use in compression ignition engines. The major factors for biofuel growth are renewable, net energy output, rural development, food security, conversion technology, biodiversity, water resource, nutrient and pesticides, feedstock and soil, change in land use, contamination and air quality.

Mixing Conditions

Mixing of biofuel and conventional hydrocarbon-based diesel are the products which are most commonly distributed for the use of retail diesel fuel bazaar (Rekhu et al., 2011). Biofuel blends like, 10% biodiesel, 90% petro diesel is labeled BD1, 20% biodiesel, 80% petro diesel is labeled BD2, 30% biodiesel, 70% diesel is labeled BD3. Coconut oil like any other vegetable oils and animal fats are triglycerides, inherently containing glycerin. Transesterification is the process involved here in which alcohol is added as a substitute for glycerin using a catalyst when it undergoes a chemical reaction. During the process the biofuel turns the oil in to esters, separating out the glycerin from the main product (Biodiesel). In addition the glycerin sinks to the bottom and the biodiesel floats on the top and can be decanted off. Reaction shows the overall reaction when one mole of TG reacts with three moles of alcohol (methanol) to produce three moles of FAME and glycerol as by-product.



In the Laboratory scale production of biodiesel from coconut oil, the following materials were used; 1 liter of coconut oil, 200 ml of methanol 99% pure, sodium hydroxide (NaOH) scales accurate to 0.1 grams. The major feedstock source used in this work is coconut oil, locally produced in India. By the stoichiometric equation of the process, 1 mol of coconut oil is essential to react with 3 moles of methanol to produce 3 moles of the biodiesel and 1 mole of glycerol. 100g coconut oil was used for the transesterification process (Md A. Hossain et al., 2012). A reaction temperature of 65°C was selected as a reaction temperature for the process and it must be below the boiling point of alcohol (methanol, 78°C) used (Van Gerpen J, 2005). Different researchers have reported the different reaction times for transesterification process as well as the entire biodiesel making process. The stated reaction time ranges from 15 minutes to 60 minutes (Chitra et al., 2005). Reaction time of 30 minutes was therefore selected. Most researchers have used 0.1 to 1.2 % (by weight of oil) of catalyst for biodiesel production. 0.8% NaOH (by weight of coconut oil) concentration was therefore selected while 20% methanol was used (Alcantara et al., 2000).

Biodiesel from Coconut Oil

This work involves the following steps during the coconut oil transesterification process. Methanol of 200 ml was mixed with 150 ml (1N) NaOH. As this is an exothermic reaction the mixture would get hot. This solution is known as sodium methoxide, which is a powerful corrosive base and also harmful to the human skin. So, safety precautions are required to avoid skin contamination during methoxide production. Sodium methoxide was added with 1 liter of coconut oil, which was preheated to about 65°C. Then the mixture was shaken for 5 minutes in a glass container, and the mixture was left for 24 hours (the longer is better) for the separation of glycerol and ester. This mixture then gradually settles down in two distinctive layers. The uppermost transparent layer is 100% biodiesel and the lower concentrated layer is glycerol. Gravity separation or a centrifuge method is to remove the heavier layer. In some cases if the coconut oil contains heavy impurities, a thin white layer is formed in between these two layers. Then the biodiesel has been washed with distilled water in order to take out waste and a dry wash has been done by air-stone (Evangelos G. Giakoumis, 2012; Kanthavelkumaran et al., 2015).

Formation of Biodiesel in the above mentioned process contains moisture (vaporization temperature 100°C) and methanol (vaporization temperature 60°C). Washing is the process involved in the formation of biofuel. Mainly, collected biodiesel after transesterification process was it was taken into a beaker. Hot water (40°C) was drizzled into the biodiesel gradually. Then the mixtures of biofuels were shaken slowly and the solution was kept for minimum four hours in the steady position. Then a layer of soap has produced in the bottom of beaker. The process had been repeated 4 times and gradually the soap formation was limited and there by the biodiesel was collected from that. An air stone was used for producing bubbles in the solution for dry wash. Dry wash confirmed the formation of glycerol and soap rest in the mixture. A heater was used which had been kept always at 35°C for removing the water from biodiesel. After this process the biodiesel was collected and its properties were tested in the laboratory.

The important fuel properties were tabulated in Table 1. The engine was initially fuelled with diesel fuel to provide the baseline data and then, it was fuelled with biodiesel blend fuels. Before stopping the test engine after each test with biodiesel blend fuels, the engine was switched on with diesel fuel until all the biodiesel based blend is purged from the fuel lines, injection pump and injector to avoid clogging while the engine cools down. The performance test was carried out at maximum load keeping throttle 100% wide open. Diesel Engine performance data were conducted for all fuels like diesel, BD1, BD2 and BD3. The emissions of different pollutants were measured at 2200 rpm at 100%, 90% and 80% throttle position.

Table 1. Fuel Properties

Parameters	Diesel	BD1	BD2	BD3
Flash Point, ºC	78	82	84	86
Cetane Number	51.5	51.8	53.2	54.2
Heating value (MJ/kg)	46.23	45.937	46.214	46.357
Density @ 40ºC (gm/cm^3)	0.821	0.822	0.823	0.825
Kinematic Viscosity @40ºC (cSt)	3.315	3.354	3.437	3.472

EXPERIMENTAL SETUP AND PROCEDURE

Fig 1 shows that the arrangement of experimental setup. This consists of engine test bed with fuel supply system and different measuring and metering devices with the engine. Separate fuel tank had been used for direct use of coconut oil for mixing with diesel. Single tank has been used for testing biodiesel performance and a typical heater was used to preheat the oil both for bio diesel and the direct using of oil. All engine performance data were measured using the dynamometer to set the engine in the particular speed level. Therefore, the experimentation tests were conducted at the engine speeds ranging between 1500 to 2300 rpm with intervals of 200 rpm conditions.

Brake power (BP), Brake specific fuel consumption (BSFC) of the engine was measured for Diesel, BD1, BD2 and BD3 blends. Test engine specification is shown in Table 2. An exhaust gas analyzer was used to measure the hydrocarbon (HC) in part per million (ppm) whereas, carbon monoxide (CO) and carbon dioxide (CO_2) were measured in percentage volume (%vol). NOx emission was also measured using exhaust gas analyzer.

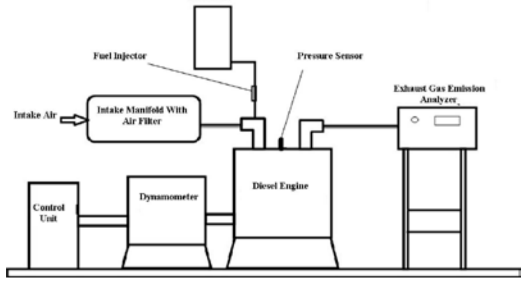


Fig 1. Schematic of Experimental set up and Engine arrangement

Table 2. Test Engine specification

Engine Type	Four stroke DI Diesel Engine
Number of Cylinder	Single
Cylinder bore x stroke	92mm x 96mm
Compression Ratio	17.7
Engine speed	2400rpm (Maximum)
Engine Power	4.5 kW
Fuel Injection Pump	Bosch Type
Injection Pressure	200 kg/cm^2
Injection Timing	bTDC 17^o
Displacement	0.638 L
Maximum Torque	4.42 kgf m
Specific Fuel Consumption	169 gr/hp h

RESULTS AND DISCUSSION

Engine performance analysis

Fig 2 shows the variations of brake power that depends upon the engine speed. Engine speed increases till 2300 rpm and brake power also increases. It will decrease due to the effect of higher frictional force. The engine brake power for biodiesel blends was found to be lower than diesel fuel. The lower brake power for BD1, BD2 and BD3 can be with an effect of low amount of heating values.

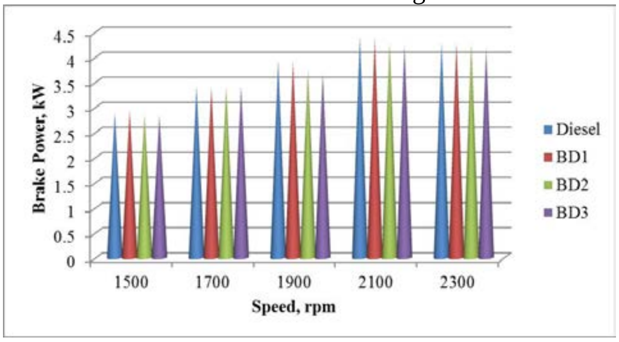


Fig. 2. Variation of Brake Power with speed

The average power drop is compared to diesel fuel over all the speed limit and is found as 0.5% to 3%.

Fig.3 represents the BSFC for diesel fuel and biodiesel blends as a function of engine speed. Engine performance is better while using biofuel blends as a fuel in diesel engine. When looked into, the heating value is slightly higher than that of diesel fuel when compared with biofuel blends.

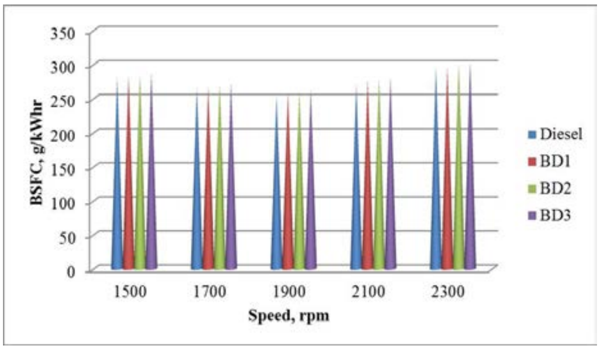


Fig. 3. Variation of BSFC with speed

From the output of the engine it was noted that it requires larger mass fuel flow, which increases the BSFC to balance the reduced chemical energy in the fuel. The average increase in BSFC compared to diesel fuel is found to be in the range of 0.5% to 2.5% of biofuel blends.

EXHAUST EMISSION ANALYSIS

Hydrocarbon (HC) emission

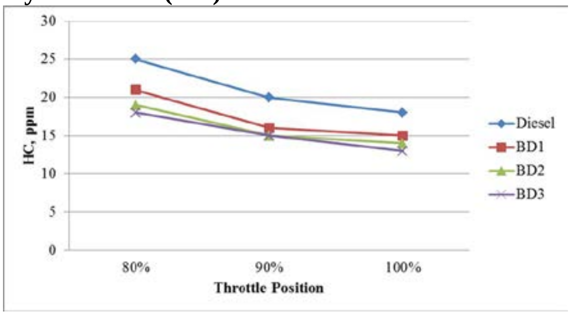


Fig. 4. Variation of HC Emission Level

Fig. 4 shows the hydro carbon emission strategy of the diesel engine for various throttling conditions. It has been observed that the oxygenated compounds were available in the biofuel blends. It was improving the fuel oxidation and thus it reduces HC emissions. Furthermore, higher cetane number of biodiesel blends reduces the combustion delay, and such a reduction has also been related to decreases in HC emissions. Compared to diesel fuel, reduction in HC at 2200 rpm and 100% throttle position was found as 15% for BD1 and 23% for BD3 respectively, like that both 90% and 80 % throttle position, HC emission was reduced to huge level.

Carbon dioxide (CO_2) emission

Fig. 5 represents the carbon dioxide (CO_2) emissions for diesel fuel and biodiesel blends at maximum speed at 100%, 90% and 80% throttle position. In this case CO_2 emission was increased while using biofuel blends compare with diesel.

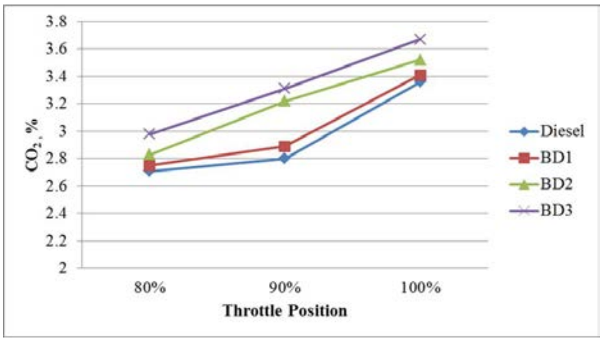


Fig. 5.Variation of CO_2 Emission Level

Maximum amount of CO_2 in exhaust emission designates the complete combustion of fuel. CO_2 for biodiesel blends at maximum speed and 100% throttle position was increased around 3% to 5% when compared to diesel fuel.

Carbon monoxide (CO) emission

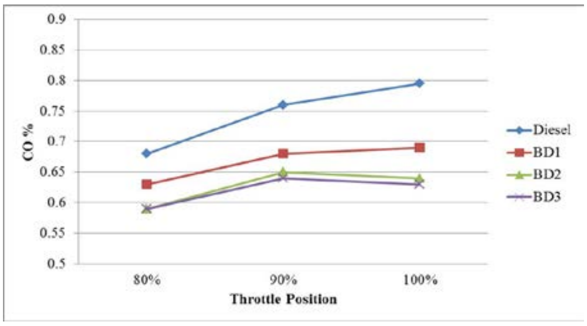


Fig. 6. Variation of CO Emission Level

Fig. 6 shows the values of CO emission in different throttle position and various fuels. CO is one of the major compounds formed during the midway of fuels and is formed mainly due to incomplete combustion of fuels. If combustion gets completed CO is converted to CO_2. Biodiesel blends as a fuel in diesel engines, CO emissions were lower than that of diesel fuel, due to some extra oxygen contents, which convert CO to CO_2 and its final outcome is incomplete combustion of the fuel when biodiesel blends are added as a fuel in diesel engines. In another study, it has been reported that higher cetane number of biodiesel blends; results in the minimum possibility of formation of rich fuel zone and thus reduces CO emissions. Average reduction in CO at maximum speed and 100% throttle position was obtained at 14% for BD1, 16.5 % for BD2 and 21 % for BD3, whereas, at 80% throttle position, reduction in CO was noted from 6% to 16% for biofuel blends.

Nitrogen oxide (NOx) emission

NOx emissions for the blends are found to be higher than that of diesel fuel. It has been reported that formation of NOx emissions are strongly dependent upon the equivalence ratio, oxygen concentration and burned gas temperature. The increase in NOx compared to diesel fuel at maximum speed and at 100% throttle position was observed as 1.5% for BD1 and 3.5% for BD3 whereas, at 80% throttle position, it increases as 2.5% for BD1, 3.2% for BD2 and 5% for BD3 respectively.

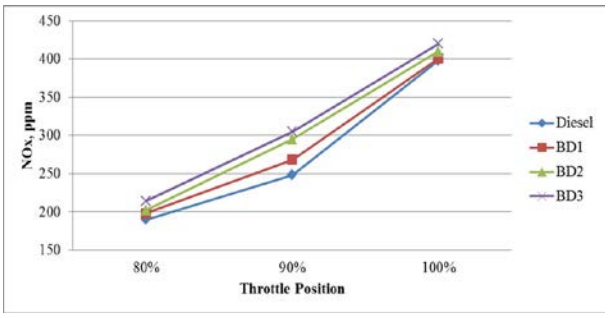


Fig.7. Variation of Oxides of Nitrogen Emission Level

Emissions of soot have been connected to respiratory diseases and are normally reflected to be a human health hazard. Basically this kind of biofuel blends will act as to support the environment health and it will reduce the soot level. When we use Biodiesel as a fuel in engines, its exhaust has a less harmful impact on human health than petroleum diesel fuel. In favor of this illustration, the United States is ready to use 25% ethanol within 2020, Brazil targets to implement 30% within 2020 and India targets to use 35% within 2017.

Smoke Density

Smoke Density for the blends are found to be lower than that of diesel fuel shows in fig. 8. It has been reported that formation of smoke emissions are strongly dependent upon the exhaust gas temperature. Smoke Density at maximum speed and 100% throttle position was obtained at 25HSU for BD1 and BD2 and 23HSU for BD3, whereas, at 80% throttle position, reduction in smoke density was noted from 19HSU to 20.5HSU for biofuel blends.

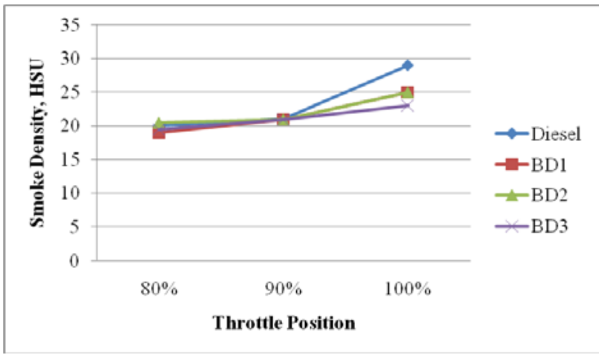


Fig. 8. Variation of Smoke density Level

It was noted that BD3 at 100% throttle position emits lowest smoke than other blends.

CONCLUSIONS

In the present scenario, biodiesel can be used as a noble alternative source of CI engines. Even the production cost of biodiesel is high, it is environment friendly and considered as a best source of renewable energy. Biodiesel production from coconut oil is relatively higher than soybean and rapeseed. In connection with environmental benefits, cost is the major factor behind these developments in Asian Continent. This work represented the investigational findings like engine performance and emissions of utilizing diesel fuel as standard and biodiesel mixes, for example, BD1, BD2 and BD3 separately. The experimental results of this research work can be précised as follows.

- ✓ Compared to diesel fuel, brake power for biodiesel blends was diminished, principally due to their respective lower heating values. The BSFC values for biodiesel blends were higher when compared to diesel fuel due to lower heating values and higher densities.
- ✓ In case of engine exhaust gas emissions, HC and CO emissions were reduced whereas, $CO_2$and NOx emissions were increased for BD1, BD2 and BD3 when compared to diesel fuel at all engine operating conditions. Also it was concluded that BD3 was the best blend based on the smoke density when compared with the other blends examined.
- ✓ From this research outset that, it is found that emission is largely responsible for greenhouse gas emission and health hazards. This kind of problem could be solved by using biofuel in diesel engines in a blended form as biofuel have potential to reduce engine emission to the environment.

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