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Performance and Emission Analysis of Diesel Engine Fuelled with Karanja oil and Diesel

Prof. Vimal V Prajapati, Dr. Ratnesh Shukla,
Dr. Tushar M. Patel and Dr. Radhashyam Giri

1. *Associate Professor, Mechanical Engineering, Government Engineering College, Near Animal Vaccine, Centre Sector -28, Gandhinagar-382028, Gujarat, India.*
2. *Professor, Mechanical Engineering, Government Engineering College, Bharuch, Opp. Govt. Guest House, Bholav, Bharuch-392002, Gujarat, India.*
3. *Professor, Mechanical Engineering, LDRP-ITR, Gandhinagar, India 382016*
4. *Assistant Professor, Central Institute of Plastics Engineering and Technology, Plot no-630, Phase IV, GIDC, Vatva, Ahmedabad-382445, India.*

Abstract

This paper evaluates the possibility of using Karanja oil from Karanja seed by chemical extraction process and mixing of the diesel in varying volume proportions in order to prepare a number of test fuels for engine application. The prepared test fuels are used in single cylinder water cooled diesel engine at various load conditions to evaluate the performance and emission parameters of the engine. Performance and exhaust emissions of diesel engine have been experimentally investigated with neat karanja oil (K100) and its blend (K10, K20, K40, K60 and K80) with diesel fuel. Engine performance parameters namely break thermal efficiency, specific fuel consumption (SFC) and mechanical efficiency of CO, HC, CO_2 and NOx were determined for different loading conditions and at constant engine speed of 1500 rpm. The test result indicates that there is a slight decrease in brake thermal efficiency and increase in specific fuel consumption for all the blended fuels when compared to that of diesel fuel with respect to increase in load. The drastic reduction in carbon monoxide and hydrocarbon were recorded for all the blended fuels as well as with neat biodiesel. However, in the case of oxides of nitrogen, there is a slight increase for all the blended fuels and with neat biodiesel when compared to diesel fuel with respect to increase in load. On the whole, karanja oil and its blends with diesel fuel can be used as an alternative fuel for diesel in direct diesel engines without any significant engine modification.

Keywords: Karanja oil, Performance, Emission and Consumption

1. INTRODUCTION

Now a day the price of petroleum oil reaches a new high, the need of developing alternate fuels has become acute. Alternate fuels should be economically attractive in order to compete with currently used fossil fuels (Jinlin et al., 2011). Biodiesel, produce by the transesterification of vegetable oils or animal fats with simple alcohols and catalyst attracts more and more attention recently (Liaquat et al., 2013). Biodiesel is clean burning diesel alternative and has many attractive features including renewability, biodegradability, non toxicity and low emission. India is one of the fastest developing countries with a stable economic growth, which multiplies the demand for transportation in many folds (Buyukkaya et al., 2010). Fuel consumption is directly proportionate to this demand. India depends mainly on imported fuels due to lack of fossil fuel reserves and it has a great impact on economy. India has to look for an alternative to sustain the growth rate. Bio-diesel is a promising alternative for our Diesel needs. With vast vegetation and land availability, certainly bio-diesel is a viable source of fuel for Indian conditions. Recent studies and research have made it possible to extract bio-diesel at economical costs and quantities (Tesfa et al., 2012). The blend of Bio-diesel with fossil diesel has many benefits like reduction in emissions, increase in efficiency of engine, higher Cetane rating, lower engine wear, low fuel consumption, reduction in oil consumption etc. It can be seen that the efficiency of the engine increases by the utilization of Bio-diesel. This will have a great impact on Indian economy. The fossil fuel demand is continuously increasing world over resulting in rapid depletion of fossil fuel deposits (Jindal et al., 201). According to the US department of energy, the world's oil supply will reach its maximum production and midpoint of depletion sometime around the year 2020 (Iwai et al., 2000). In several studies, it has been experimentally investigated that the human health hazards are associated with exposure to diesel exhaust emissions (Vincent et al., 2003). Therefore, limited fossil fuels and intensified environment pollution, it has become a global issue to develop such clean fuel, which is technically feasible, domestically available and environmentally acceptable (Liaquat et al., 2010). Generally, recommended biodiesel for use as a substitute for petroleum-based diesel is produced from vegetable oil or animal fats by transesterification process. Biodiesel is an oxygenated, renewable, biodegradable and environmentally friendly bio-fuel with low emission profile (Hirkude et al., 2012). According to experimental results conducted by various researchers around the world, it has been reported that biodiesel fuelled engine produced marginal loss in engine torque and power, and increase in bsfc as compared to diesel fuel. Besides that, it reduces the emissions of carbon monoxide (CO), hydrocarbon (HC), sulfur dioxide (SO2), polycyclic aromatic hydrocarbons (PAH) and nitric polycyclic aromatic hydrocarbons (nPAH). However, a majority of research results have indicated an increase in nitrogen oxides (NOx) (Machado et al., 2008). According to the study (Altin et al., 2013) conducted on a six cylinders direct injection diesel engine, it has been reported that the increase of biodiesel percentage in the blend involves a slight decrease of both power and torque over the entire speed range. In particular, with pure biodiesel there was a reduction by about 3% maximum power and about 5% of maximum torque. Moreover, with pure biodiesel, the maximum torque was found to have reached at higher engine speed. Similar results were investigated by Aydin and Bayindir (Aydin et al., 2010) using cottonseed oil methyl ester (CSOME). However, a decrease of CO, NOx and SO2 emissions were observed in the same study. In another study (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.

2. MATERIALS AND EXPERIMENTAL METHODS

2.1 KARANJA OIL

Karanja is a tree and is green during summer, adds to natural beauty, helps provide cool air, and shelter. It needs no pesticides for plantations and growing and average rainfall required is 500-2500 mm. The plant life is 80-100 years and seeds start yielding at 5th/6th year onwards and around 8/10 years onwards gives income up to Rs. 24,000 per year, per acre. Karanja trees can be normally planted along the highways, roads, and canals to stop soil erosion. Billions of trees exist all over India. If the seeds fallen along road side are collected, and oil is extracted at village level expellers, thousands of tons of oil will be available. The karanja biodiesel used for this study is available commercially and conforms to the standards specified in ASTM-D-6751. The steps carried out during the preparation of biodiesel are shown in Figure-2. Seeds of karanja are crushed through an oil expeller, which separates oil and cake. The oil is filtered and passed through a chemical reactor for mixing it with methanol in presence of a catalyst. Here fatty acids are separated, and esterification process takes place. The end product is biodiesel. Byproduct glycerin is separated and excess methanol is recovered.

Figure-1. Karanja tree and seeds.

2.2. Physical and chemical properties of Karanja oil

The physicochemical properties of karanja oil, which are shown in the Table-1.

Table-1. Physical and chemical properties of karanja oil.

Properties	Unit	Test values
Density	Gm/cc	0.927
Kinetic viscosity @ 40^0C	Mm^2/s	40.2
Acid value	MgKOH/gm	5.40
Pour point	^{0}C	6
Cloud point	^{0}C	3.5
Flash point	^{0}C	225
Calorific value	MJ/Kg	8742
Saponification value		184
Carbon residue	Wt%	1.51
Specific gravity		0.936

2.3 KARANJA OIL: A SOURCE OF BIODIESEL

Transesterification reaction

Transesterification or alcoholysis is the displacement of alcohol from an ester by another in a process similar to hydrolysis, except an alcohol is used instead of water [3]. This process has been widely used to reduce the high viscosity of triglycerides. The transesterification reaction is represented by the general equation as below:

RCOOR' + R"OH_RCOOR" + R'OH

Some feedstock must be pretreated before they can go through the transesterification process. Feedstock with less than 5% free fatty acid, do not require pretreatment. When an alkali catalyst is added to the feedstock's (with FFA > 5%), the free fatty acid react with the catalyst to form soap and water as shown in the reaction below:

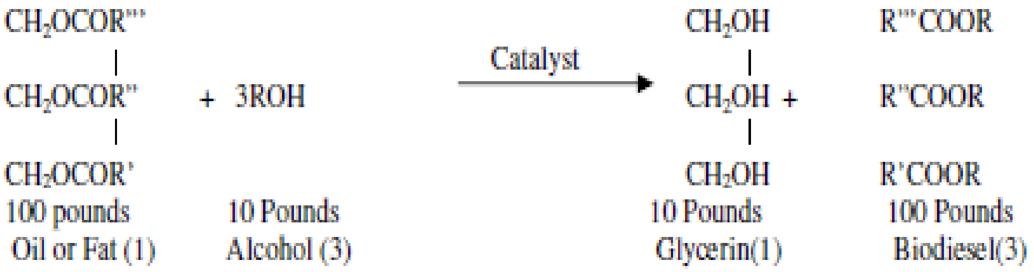

Figure-2. General equation for methanolysis of triglycerides

Table-2. Compositions of different % of karanja oil batches

Batch Code	Karanja oil %	Diesel %
K0	0	100
K10	10	90
K20	20	80
K40	40	60
K60	60	40
K80	80	20
K100	100	0

Sample Calculations

- (For 1 kg load at Constant speed 1500 rpm of a Diesel engine when working on diesel fuel and Palm oil blend **D90 K10**)
- Find the density of diesel and karanja oil blend of **D90 K10**.

$$\frac{volume \text{ of diesel } V_D}{volume \text{ of karanja oil } Vp} = \frac{\rho_{\underset{oil}{karanja}} - \rho_{\text{blend}}}{\rho_{blend} - \rho_{Diesel}}$$

$$\therefore \frac{90}{10} = \frac{860 - \rho_{blend}}{\rho_{blend} - 833}$$

$$\therefore \rho_{blend} = 835.7 \text{ Kg/m}^3 = 0.8357 \text{ Kg/ lit}$$

- Find the calorific value of diesel and palm oil blend of **K10**.

$$CV = \frac{\text{md CVd} + \text{mp CVk}}{\text{m blend}}$$

$$= \frac{(0.900*0.833)*42850 + (0.100*0.860)*37000}{1*0.8357}$$

= 42247.98 kJ/kg

Brake Power

$$BP = \frac{2\pi NT}{1000 * 60} \text{KW}$$

BP = 2Π*1689*1.65/ (60000)

= 0.29 kW

Where,

N = Brake Speed, rpm = 1689 rpm

T = Torque, n-m

$= (0.91 * 9.81) * 0.185\ Nm$

= (0.91*9.81)* 0.185

=1.65 Nm

1. Fuel Consumption

   Fuel Consumption is 8cc/min and Density of blend is835.7 Kg/m^3

   FC = (8*60*835.7) /10^6

   FC = 0.4 kg/hr

2. Specific Fuel Consumption

   $SFC = \frac{FC}{BP}$ Kg/KWH

   SFC = 0.4 / 0.29

   SFC = 1.37 kg/kWh

3. Heat Supplied By Fuel

$H_F = FC * 42247.98\ KJ/hr$

H_f = 0.4*42247.98= 16899.19 kJ/hr

Where, calorific value of blend of **K10** is 42247.98 kJ/kg.

4. Plot the graph of FC v/s BP for different readings. Extend the line to meet zero FC. The power (on negative side) at which FC is zero is friction power, FP. The plot is known as Willian's Line. FP = 1.955307 kW (from graph)

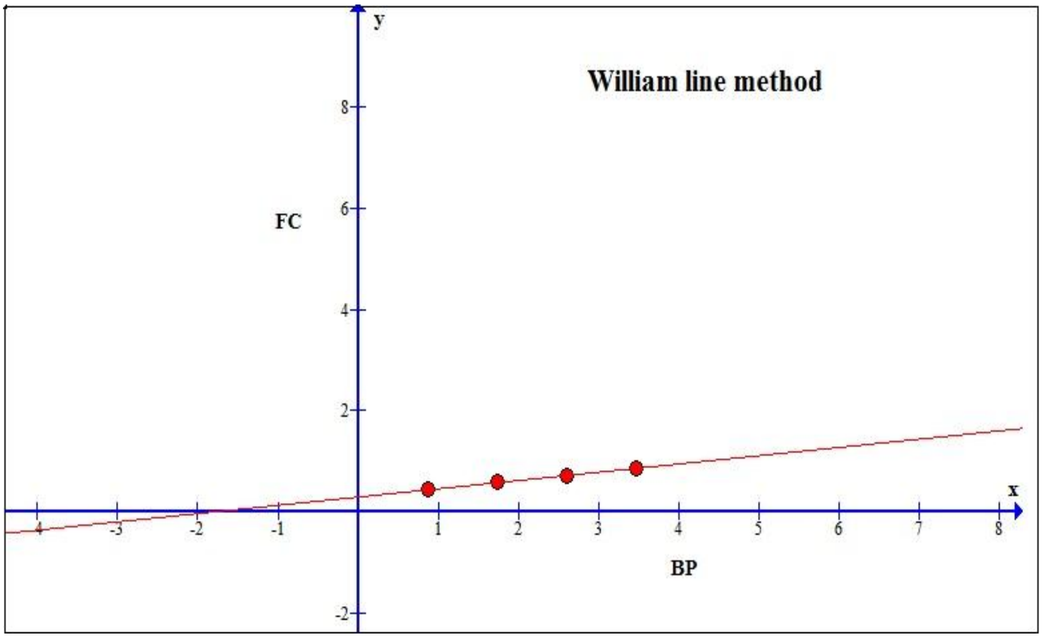

Figure-3. Williams line method

Indicated Power,

$IP = FP + BP\ KW$

IP = 1.88 + 0.29 = 2.17 kW

5. Heat Equivalent To Bp

$H_{BP} = BP * 3600\ kJ/hr$

H_{BP} = 0.29*3600
= 1044 kJ/hr

6. Heat Equivalent To IP,

$$H_{IP} = IP * 3600 \frac{kJ}{hr}$$

H_{IP} = 2.17 * 3600
= 7812kJ/hr

7. Efficiency,

   i) Mechanical Efficiency

   $$\eta_m = \frac{BP}{IP} * 100\%$$

   = (0.29/2.17)*100)

   = 13.36%

   ii) Brake Thermal Efficiency,

   $$\eta_{BT} = \frac{\text{HEAT IN BP}}{\text{HEAT SUPPLIED BY FUEL}} * 100\%$$

   = (0.29*100) / 0.4/3600*42247.98

   = 6.22%

   Other calculation is to be finding out by similar way at different load and different blend.

3. RESULTS AND DISCUSSIONS

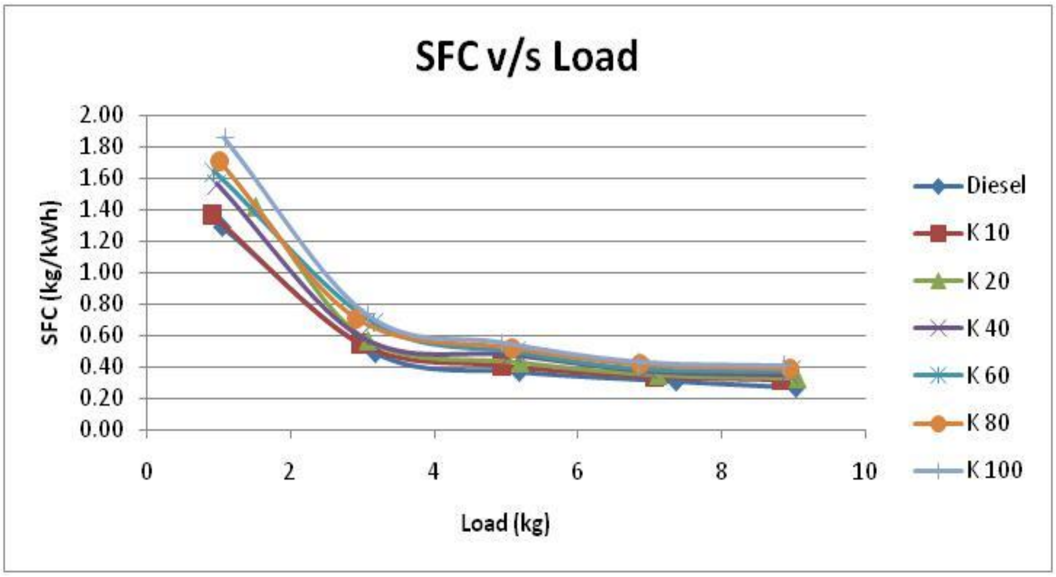

Figure 3.1 Comparison of SFC (kg/kWh) for various Karanja biodiesel blends with diesel (for different load)

Figure 3.1 shows as load increases SFC (specific fuel consumption) decreases for the all the blends Comparing SFC of diesel engine for pure diesel to K10, K20, K40, K60, K80, K100 fuel increases in SFC of engine At partial load are 10.81%, 16.22%, 29.73%, 35.14%, 40.54%, 48.65% and At full load are 18.52%, 22.22%, 29.63%, 40.74%, 44.44%, 51.85% respectively so at partial load full load K10 blend minimum increases in SFC is better performance and SFC of engine near to diesel fuel.

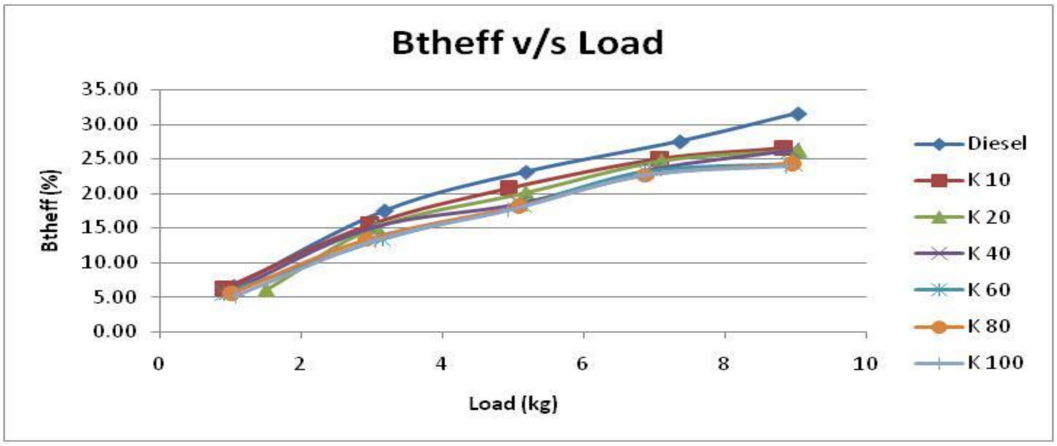

Figure 3.2 Comparison of (Btheff, %) for various Karanja biodiesel blends with diesel (for different load)

It is also seen that at lower load SFC increases minimum for K10 and K40 are 6.20%, 10.08% respectively. It is observed that BSFC decreases for all the test fuels with increase in load. It is seen that BSFC is highest for pure biodiesel and lowest for diesel because of high viscosity, density, low volatility and low heat content of pure biodiesel when compared with that of diesel. Figure 3.2 shows as load increases Btheff (%) increases for the all the blends. Comparing break thermal efficiency of diesel engine for pure diesel to K10, K20, K40, K60, K80, K100 fuel Decrease in break thermal efficiencies of engine At partial load 8.46%, 11.47%, 18.68%, 19.07%, 20.21%, 22.64% and At full load are 14.37%, 15.78%, 15.85%, 21.68%, 21.92%, 23.10% respectively so at partial load B10, B40 and for full load B10 minimum decreases in Break thermal efficiency. The variation in Break thermal efficiency (BTE) of the engine with diesel fuel, karanja oil and its blend is shown in Figure 3.1. Thermal efficiency is the ratio between the power output and the energy introduced through fuel injection, the latter being the product of the injected fuel mass flow rate and the lower heating value. It can be seen from Figure 3.1 that thermal efficiency in general, decreases with increasing proportion of biodiesel in the test fuels. This is due to the higher viscosity, density and lower heat value than the diesel fuel. The higher viscosity leads to decreased atomization, fuel vaporization and combustion and hence the thermal efficiency of biodiesel is lower than that of diesel fuel. The K10 and K20 blended fuel is very close to diesel fuel. Thus the difference in BTE between diesel fuel and K40 blend is very significant at maximum load. Fuel consumption increases due to higher density and lower heating value consequently, brake thermal efficiency decreases. However the BTE of blended fuels is higher than that of neat biodiesel.

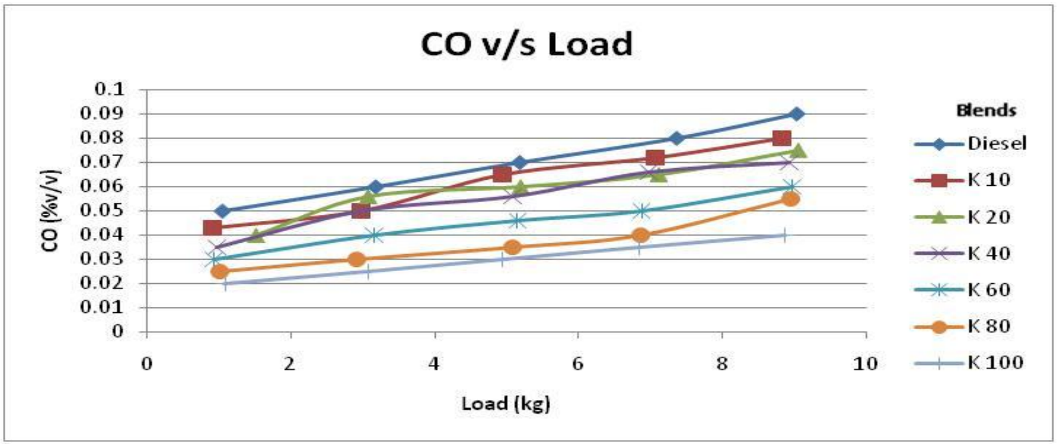

Figure-3.3 Comparison of CO (%v/v) for various Karanja biodiesel blends with diesel (for different load)

Figure 3.3 shows the variation in CO emission with respect to variation in load as load increases CO (%v/v)increases for the all the blends. Comparing CO Emission of diesel engine for pure diesel as fuel CO emission decreases for K10, K20, K40, K60, K80, K100 At partial load are 7.14%, 14.29%, 20%, 34.29%, 50%, 57.14% and At full load are 11.11%,16.67%,22.22%,33.33%,38.89%,55.56% respectively . at partial load as well as at full load K100 fuel minimum engine CO emission. it is seen that at partial load K80 (50%,) also less CO emission. CO emission is highest for pure biodiesel because of poor spray characterization that results in improper combustion which gives rise to CO formation.

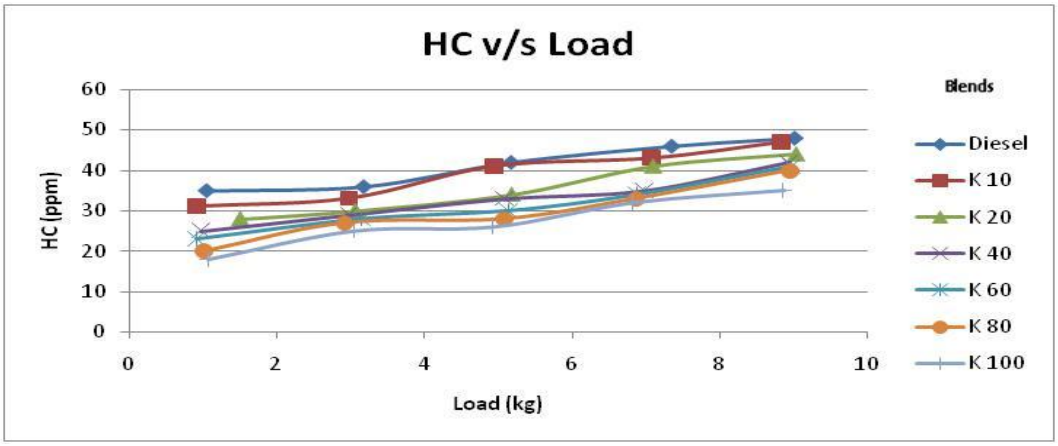

Figure-3.4 Comparison of HC (ppm) for various Karanja biodiesel blend with diesel (for different load)

Figure-3.4 Comparison of HC (ppm)for various Karnja biodiesel blend with diesel (for different load) Comparing HC Emission of diesel engine for pure diesel as fuel HC emission decreases K10, K20, K40, K60, K80, K100 At partial load are2.38%, 19.05%, 21.43%, 28.57%, 33.33%, 38.10% and At full load are 2.08%, 8.33%, 12.50%, 14.58%, 16.67%, 27.08% , respectively at partial load and at full load K100 fuel maximum decreases in HC emission and it is seen that for partial load B80 fuel HC emission near to B100 From Figure 3.4, it is understood that biodiesel produces less HC emission in comparison to that of diesel because of better combustion of the test fuel and its blend with additive due to presence of oxygen.

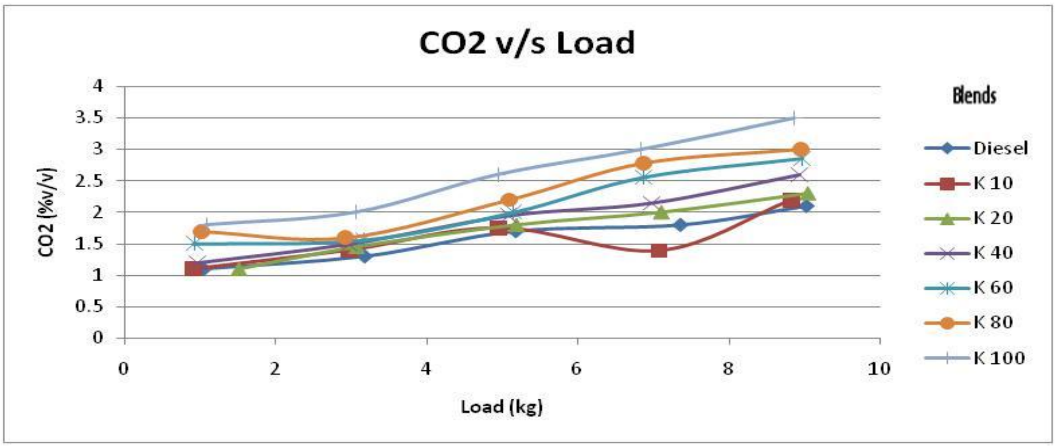

Figure-3.5 Comparison of CO_2 (%v/v) for various Karanja biodiesel blends with diesel (for different load)

Figure-3.5 shows, it can be observed that CO_2 increases with increases in load for all fuels tested. The trends observed may be because of more fuel being burnt at higher loads due to which more carbon is available to form CO_2. Comparing CO_2 Emission of diesel engine for pure diesel as fuel CO_2 emission increases for K10, K20, K40, K60, K80, K100 At partial load are 2.94%, 5.88%, 14.71%, 17.65%, 29.41%, 52.94% and At full load 4.76%, 9.52%, 23.81%, 36.19%, 42.86%, 66.67% respectively. At, partial load and at full load K10 fuel minimum Increases in CO_2 emission.

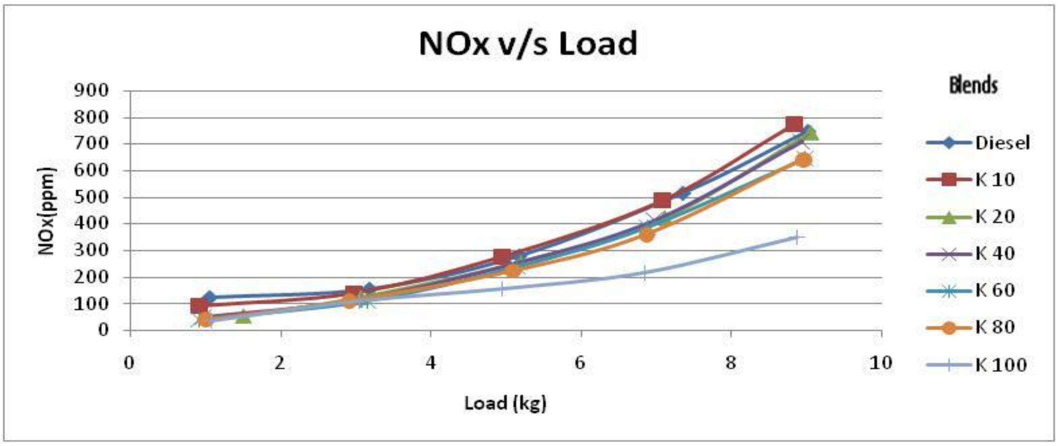

Figure-3.6 Comparison of NOx (ppm) for various Karanja biodiesel blends with diesel (for different load)

Figure-3.6 shows the variation of NOx emission for diesel fuel as load increases NOx (ppm)increases for the all the blends Comparing No_x Emission of diesel engine for pure diesel as fuel No_x emission decreases for, K20, K40, K60, K80, K100 At partial load are 9.29%, 10.71%, 14.29%, 20.36%, 45.00% and At full load are 1.20%, 5.07%, 13.89%, 14.15%, 53.54% respectively .It is seen for K10 blends at partial load No_x emission decrease by1.07% and at full load its increases by3.43% so at partial load and at full load B100 fuel maximum decreases in No_x emission.

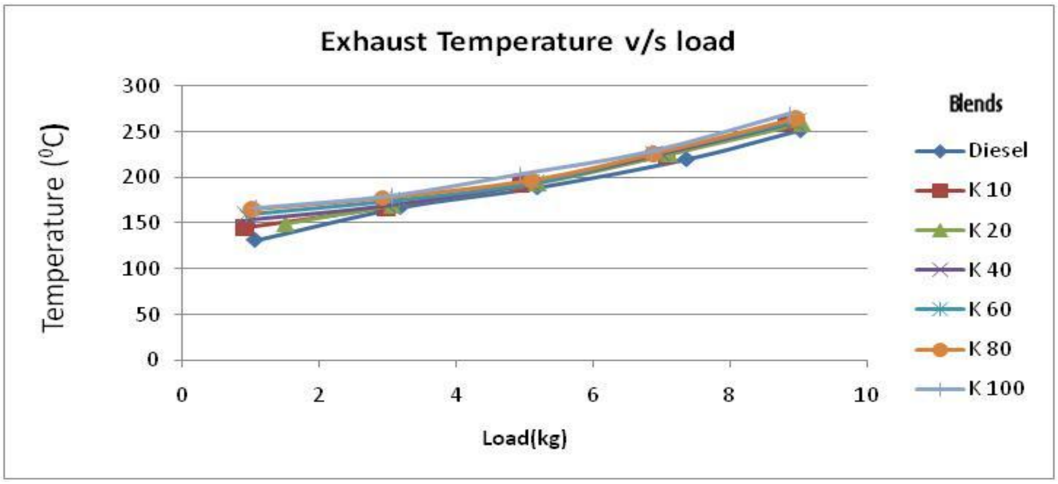

Figure-3.7 Comparison of Exhaust Temperature(°C)) for various Karanja biodiesel blends with diesel (for different load)

Figure-3.7 shows The variation of Exhaust gas temperature (EGT) with respect to load for diesel fuel, biodiesel and its blend as load increases Exhaust

Temperature(°C)increases for the all the blends. Comparing EGT of diesel engine for pure diesel as fuel EGT increases for K10, K20, K40, K60, K80, K100 At partial load are 2.03%, 2.04%, 2.37%, 2.71%, 4.41%, 7.63% and At full load are 3.13%, 2.60%, 3.22%, 4.05%, 5.32%, 7.10% respectively. At, partial load and at full load for B10 fuel minimum increases in EGT. It is also seen for partial load and K20, K40, K60 blends and for full load K20 and K40 are good blends of karanja biodiesel with diesel for considering EGT.

4. CONCLUSIONS

During the present investigation several tests were carried out on a four stroke single cylinder inject diesel engine using diesel and karanja biodiesel at different proportions. From the experimentation following conclusions were drawn.

a. Break thermal efficiency (BTE) in case of diesel, K10, K20, K40, K60 and K80 the thermal efficiency, decreases with increasing proportion of biodiesel in the test fuels. This is due to the higher viscosity, density and lower heat value than the diesel fuel.
b. Brake specific fuel consumption (BSFC) for diesel, K10, K20, K40, K60 and K80, decreases for all the test fuels with increase in load. It is seen that BSFC is highest for pure biodiesel and lowest for diesel because of high viscosity, density, low volatility and low heat content of pure biodiesel when compared with that of diesel. Exhaust gas temperature is found highest for pure biodiesel. This may be due to high combustion temperature of biodiesel because of high oxygen content.
c. Hydrocarbon emission increases with that of load for all prepared test fuels. it is understood that biodiesel produces less HC emission in comparison to that of diesel because of better combustion of the test fuel and its blend with additive due to presence of oxygen. HC emission for diesel, K10, K20, K40, K60 and K80 increase with increase in load for all prepared test fuels.
d. It is observed that CO emission decrease with increase in load for all prepared test fuels. CO emission is highest for pure biodiesel because of poor spray characterization that results in improper combustion which gives rise to CO formation.

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