PERFORMANCE EVALUATION OF DIESEL ENGINE USING BLENDS OF KARANJA OIL

A DISSERTATION

Submitted in partial fulfillment of the Requirements for the award of the degree of

MASTER OF TECHNOLOGY

in

ALTERNATE HYDRO ENERGY SYSTEMS

By

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I extend my thanks to all classmates who have given their full cooperation and valuable suggestions for my dissertation work.

Last but not the least; I would like to express my humble respect and special thanks to my parents, others who directly or indirectly helped me during completion of this dissertation work.

Dated: June 30, 2010

(JADHAV VISHAL PRABHAKAR)

CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in this dissertation, entitled, "**PERFORMANCE EVALUATION OF DIESEL ENGINE USING BLENDS OF KARANJA OIL**", in partial fulfillment of the requirement for the award of the degree of **Master of Technology** in "**Alternate Hydro Energy Systems**", submitted in Alternate Hydro Energy Centre, Indian Institute of Technology, Roorkee is an authentic record of my own work carried out during the period from July 2009 to June 2010 under the supervision of **Dr. M.P.SHARMA**, Associate Professor Alternate Hydro Energy Centre, Indian Institute of Technology, Roorkee, India.

I have not submitted the matter embodied in this dissertation for award of any other degree.

Dated: June30, 2010
Place: Roorkee

(JADHAV VISHAL PRABHAKAR)

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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ABSTRACT

Karanja (Pongamia pinnata) oil, a non-edible high viscosity (27.84 cSt at 40°C) straight vegetable oil, is blended with conventional diesel in various proportions to evaluate the performance and emission characteristics of a single cylinder direct injection constant speed diesel engine. Diesel and karanja oil fuel blends (B5, B10, B15, B25, and B30) were used to conduct short-term engine performance and emission tests at varying loads (20%, 40%, 60%, 80%, and 100%). Tests were carried out over the entire range of engine operation and engine performance parameters such as fuel consumption, thermal efficiency, exhaust gas temperature, and exhaust emissions were recorded.

The brake thermal efficiency (BTE), brake specific energy consumption (BSEC), and exhaust emissions were evaluated and compared with diesel fuel determine the optimum fuel blend. A fuel blend of 10% karanja oil (B10) showed higher BTE at a 60% load as compared with other blends but it is slightly lower than diesel. Similarly, the overall emission characteristics were found to be best for the case of B10 over the entire range of engine operation.

Exhaust gases emission were measured with the help of AVR 2 gas analyzer. The temperature of exhaust gases coming out of the engine gives an indication of the thermal efficiency of the engine. Heat loss is important for engine as it leads to lower working temperature and ultimately to reduced efficiency. The combustion is supposed to be completed at the end of the constant pressure burning, however in actual practice it continues up to about half of the expansion stroke. In general about 30 per cent of the energy supplied to diesel engine is lost as exhaust heat. The exhaust gas temperature depends upon the fuel-air ratio and combustion characteristics of the fuel, which in turn may depend upon the type of fuel and loading conditions as well as engine compression ratio and injection timing.

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CHAPTER-1

INTRODUCTION AND LITERATURE REVIEW

1.1 ENERGY SCENARIO OF WORLD

The major sources of energy in the world are oil, coal, natural gas, hydro energy, nuclear energy, renewable combustible wastes and other energy sources. Combustible wastes include animal products, biomass and industrial wastes. In 1999, the total supply of primary energy in the world was 9,744.48 MTOE (Million Tons of Oil Equivalent). According to estimates of 1999, the total supply of energy in the world in 2010 is projected to be 11,500 MTOE and that in 2020 is expected to be 13,700 MTOE.

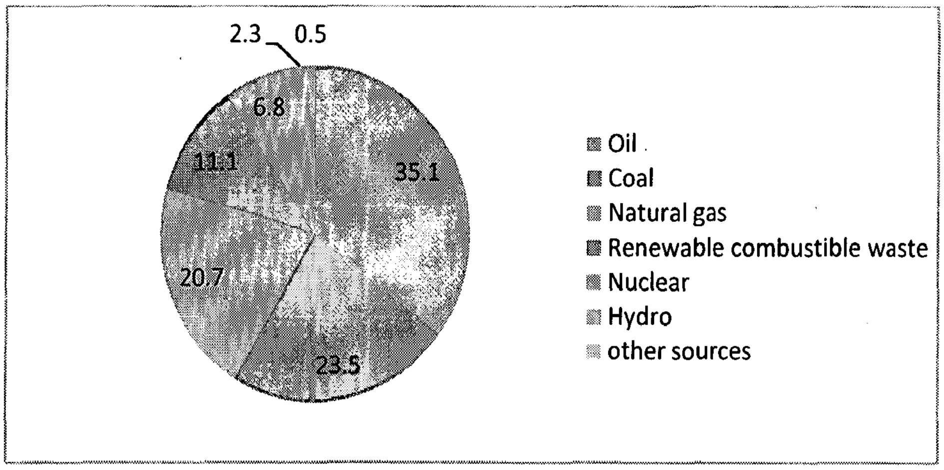


Figure 1.1 Proportion in which energy from different sources was consumed in the world in 2010[1]

The energy from the renewable combustible waste is 11.1% which is less compared to oil and coal which are consumed in 35.1 and 23.5 respectively. Oil is the most important and abundant source of energy in the world. It is also the most highly consumed. However price of crude oil is very volatile and supply is driven by price. While developed industrialized countries consume around 43 million barrels daily on an average, developing countries consume only 22 million barrels per day on an average.

The world energy scenario depicts a picture of concern. The adverse effects on environment caused by the production and consumption of energy have resulted in severe environmental impacts across the globe. The supply of energy is expected to remain adequate in coming years. However, imbalance of energy consumption is prevalent around the world. Energy consumption is high in most developed countries. On the other hand, the developing countries need to consume more energy to ensure economic growth. According to estimates, energy consumption in developing countries is only one-tenth of that in the developed countries. The economic development of many countries is hindered due to "energy poverty" [1].

1.2 INDIAN ENERGY SCENARIO

India ranks sixth in the world in total energy consumption and needs to accelerate the development of the sector to meet its growth aspirations. The country, though rich in coal and abundantly endowed with renewable energy in the form of solar, wind, hydro and bio-energy has very small hydrocarbon reserves (0.4% of the world's reserve).

Table 1.1 Grid interactive power generation installed from renewable sources [2].

SOURCES	**Grid-interactive power generation installed (in MW)**	**11th Plan target (in MW)**
Wind power	3857	9000
Small hydro power	619.53	1400
Biomass power	322	500
Bagasse cogeneration	704.20	1200
Solar power	8.10	50
waste to energy	20.10	79
Total	**5531**	**12300**

The total grid-interactive power generation installed from renewable sources during the 11^{th} five year plan (2006 to 2011) is 5531MW against the target of 12300MW up to 2010.

India, like many other developing countries, is a net importer of energy, more than 25 percent of primary energy needs being met through imports mainly in the form of crude oil and natural gas. The rising oil import bill has been the focus of serious concerns due to the pressure it has placed on scarce foreign exchange resources and is also largely responsible for energy supply shortages. The sub-optimal consumption of commercial energy adversely affects the productive sectors, which in turn hampers economic growth.

1.3 RNEWABLE ENERGY POTENTIAL IN INDIA

India is the 4th largest country with regard to installed power generation capacity in the field of renewable energy sources and much is waiting to be discovered by it. Wind, Hydro, Biomass and Solar are main renewable energy sources. India has tremendous potentialities to harness the much-needed energy from renewable sources and considered as one of the ideal investment destinations for renewable energy equipment manufacturers and service providers. Wind energy has posted the highest growth. India could become top player in world's solar market. India intends to provide a reliable energy supply through a diverse and sustainable fuel mix that addresses major national drivers.

Table 1.2 Renewable energy potential in India [2]

SNo.	Sources / Systems	Achievements during 2009-10 (upto 31.03.2010)	Cumulative Achievements (upto 31.03.2010)
I. Power From Renewable			
A. Grid-interactive renewable power			
1.	Biomass Power (Agro residues)	153.30 MW	865.60 MW
2.	Wind Power	1565.00 MW	11807.00 MW
3.	Small Hydro Power (up to 25 MW)	305.27 MW	2735.42 MW
4.	Cogeneration-bagasse	295.30 MW	1334.03 MW
5.	Waste to Energy	4.72 MW	64.96 MW
6.	Solar Power	8.15 MW	10.28 MW
	Sub Total (in MW) (A)	**2330.42 MW**	**16817.29 MW**
B. Off-Grid/Distributed Renewable Power (including Captive/CHP Plants)			
7	Biomass Power / Cogeneration (non-bagasse)	50.80 MW	232.17 MW

8.	Biomass Gasifier	13.28 MWeq.	122.14 MWeq
9.	Waste-to- Energy	15.88 MWeq.	46.72 MWeq
10.	Solar PV Power Plants	0.16 MWp	2.46 MWp
11.	Aero-Generators/Hybrid Systems	0.22 MW	1.07 MW
	Sub Total (B)	**80.34 MWeq**	**404.56 MWeq**
	Total (A + B)	**2410.76 MW**	**17221.86 MW**

These include security concerns, commercial exploitation of renewable power potential, eradication of energy poverty, ensuring availability and affordability of energy supply and preparing the nation for imminent energy transition.

India is the 4th largest country with regard to installed power generation capacity in the field of renewable energy sources and much is waiting to be discovered by it. Wind, Hydro, Biomass and Solar are main renewable energy sources. India has tremendous potentialities to harness the much-needed energy from renewable sources and considered as one of the ideal investment destinations for renewable energy equipment manufacturers and service providers. Wind energy has posted the highest growth. India could become top player in world's solar market. India intends to provide a reliable energy supply through a diverse and sustainable fuel mix that addresses major national drivers. These include security concerns, commercial exploitation of renewable power potential, eradication of energy poverty, ensuring availability and affordability of energy supply and preparing the nation for imminent energy transition.

1.4 BIOMASS ENERGY

All organic matter is known as biomass and energy realized from biomass when it is eaten, burnt or converted into fuels is called biomass energy the biomass provides a clean renewable energy source that could dramatically improve our environment, economy and energy security. Biomass energy generates far less air emissions than fossil fuels.

Biomass is one of the oldest sources of energy in the world. Although we have been using it all the time, it may have been never heard about its scientific name. Biomass known as living material or specifically, it is the conversion of the stored energy in the dead trees, tree branches, wood, crops and even animals into energy so that we can use it. Biomass will not be useful for producing electrical power energy unless converted into another form. Consequently, if any company wants to use biomass as a source of energy instead of oil or gas, it will need to collect the biomass (plants, wood and so on) and burn it in special places, then the heat of this burning can be used in a steam turbine to generate electricity. In the same way, power plants can use biomass in a different process which called Gasification. In this case, biomass is going to be heated at very high temperature degrees to produce flammable gases which can be used to rotate the turbine and produce electricity. [4]

1.5 CONVERSION OF BIOMASS WASTE INTO USEABLE FUEL

i. **Gasification:**

Biogas is produced by exposing biomass to high temperatures and limited Oxygen; this biogas energy can serve as a feedstock for electricity generation for a building block for electricity generation or a building block for chemicals.

ii. **Pyrolysis:**

Heating the biomass can produce pyrolysis oil and phenol oil leaving charcoal. Pyrolysis oil is easier to store and transport than solid biomass material and can be burned like petroleum to generate electricity. Phenol oil is chemical used to make wood adhesives, molded plastics and foam insulation. Wood adhesives are used to glue together plywood and other composite wood products.

iii. **Digestion:**

Bacteria, in an oxygen-starved environment can produce methane. Anaerobic digesters composes (or "digest") organic waste in a machine that limits access to oxygen encouraging the generation of methane and carbon dioxide by microbes in the waste. This digester gas is then burned as fuel to make electricity.

iv. **Fermentation:**

Bio-material that is used to manufacture Ethanol and Biodiesel by anaerobic biological process in which sugars are converted to alcohol by the action of micro-organisms, usually yeast. Unlike other renewable energy sources, biomass can be converted directly into liquid fuels which are called as biofuels, for our transportation needs (cars, trucks, buses, airplanes, and trains). The two most common types of biofuels are ethanol and biodiesel. Ethanol is an alcohol, created by fermenting biomass high in carbohydrates. It is used as a fuel additive to cut down carbon monoxide and other emissions. Biodiesel is made by combining alcohol with vegetable oil, animal fat or other recycled cooking grease and is also an additive to reduce emissions. When pure, biodiesel is a renewable alternative fuel for diesel engines

v. **Solid Fuel Combustion:**

Direct combustion of solid matter where the biomass is fed into furnace where it is burned. The heat is used to boil water and the energy in the steam is used to turn turbines and generators. [5]

1.6 LITERATURE REVIEW

The literature is divided into two steps i.e. engine performance by using vegetable oiland emission characteristics of engine with different vegetable oils.

1.6.1 Review of literature of Engine performance studies

Alternative fuels are popularly discussed in many countries owing to increased environmental awareness and the rising price of diesel. Developing alternative diesel fuels is driven by the necessity to reduce the environmental impact of emissions without modifying engines. Using alternative fuels instead of diesel reduces the fuel consumption and improves the engine efficiency.

Moreno *et al.* (1998) assessed the performance of an automobile diesel engine with various blends (0, 25, 50, 75, and 100 %) of Sunflower Methyl Ester (SME) with diesel. The power and torque was maintained within the same levels as using pure diesel fuel, where as the specific fuel consumption increased with increase in the percentage of sunflower methyl ester in the mixture. The 25 to 50 per cent range was especially suitable when considering the performance of the diesel engine and their emissions [6].

Abdul and Jon (1999) evaluated the impact of oxidized biodiesel (Soybean based) on engine performance and emissions. A turbocharged DI diesel engine was fueled with oxidized and unoxidized biodiesel and the performance emissions were compared with No. 2 diesel fuel. The oxidized and unoxidized biodiesel had 15.1 and 13.8 per cent higher brake specific fuel consumption, respectively. The thermal efficiency of biodiesel and its blends was same as for No.2 diesel and it was 37 per cent at full load and 21 per cent at light load. Compared with unoxidized biodiesel, oxidized biodiesel produced 15 and 16 per cent lower exhaust carbon monoxide and hydrocarbons, respectively [7].

Canakci and Gerpen (2001) studied the performance of a diesel engine fueled with biodiesel from yellow grease and soybean oil were measured at full load (190 ft-lbf) and at an engine speed of 1400 rpm (Table 1.3).

Table 1.3 Brake specific fuel consumption and thermal efficiency of yellow grease and soyabean biodiesel [8]

Fuel type	**BSFC, g kWh^{-1}**	**Change in BSFC, %**	**Thermal efficiency, %**	**Change in Thermal efficiency, %**
No.2 diesel	228.42	-	36.96	-
20 % SME	234.55	2.69	36.90	-0.16
20 % YGME	234.29	2.57	36.99	0.07
SME	259.33	13.53	37.13	0.45
YGME	260.94	14.24	37.14	0.49

The performance of the engine using blends (B30, B40, B50, B60 and B70) and Jatropha oil was evaluated in a single cylinder compression ignition engine and compared with diesel. The specific fuel consumption and brake thermal efficiencies of B30 and B40 were 0.338 and 0.365 kg kWh^{-1}, and 26.09 and 24.36 per cent which were very close to diesel (0.316 kg kWh^{-1}and 27.11 %, respectively). The exhaust gas temperatures were reduced from B100 to B30 due to decrease in viscosity of the vegetable oil (Pramanik, 2001) [9].

Dorado *et al.*, (2003) have tested olive oil methyl esters in a diesel engine and reported that these esters resulted a slightly increase in brake specific fuel consumption, lower than 8.5 per cent than that of diesel. Engine performance of used olive oil methyl ester was similar to diesel fuel and no changes in operation were noticed [10].

Ramdas *et al.*, (2004) conducted a study on performance and emission evaluation of a diesel engine fueled with methyl esters of rubber seed oil and blends (B20, B40, B60, B80). The specific fuel consumption of the all fuels was decreased with increasing load (1-6 kW) and was higher compared to that of diesel. For B20 and B40, the specific fuel consumption was 0.63 kg kWh^{-1} which was same as diesel fuel. Thermal efficiency was considerably increased with blends compared to the use of rubber seed oil alone. In the case of B80, the highest thermal efficiency was observed (28 %) and B60 and diesel having same thermal efficiency (25 %). The experimental results proved that the use of biodiesel (produced from unrefined rubber seed oil) in compression ignition engine is a viable alternative to diesel [11].

Hongmei and Jun (2005) reported that the specific fuel consumption of mixed fuel 1 (mixed 10 % BOB1 with diesel) and mixed fuel 2 (mixed 10 % BOB2 with diesel) at the speed 2200 rpm was about 11.7 per cent and 6 per cent respectively which was lower than pure diesel fuel due to the lower calorific value of BOB. The mixed fuel 1 and fuel 2 can be burned totally under overloading and meet the power request for the engine. The result showed that there was no significant difference in performance between pure diesel and BOB without adjustment of engine [12].

Agarwal *et al.*, (2006) conducted a study on effect of fuel injection pressure on compression ignition engine by using Jatropha oil. For diesel, Brake Specific Fuel Consumption (BSFC) was lowest from 180 to 200 bars fuel injection pressure. Maximum thermal efficiency (31.75 %) was found at fuel injection pressure of 200 bars. Increase in fuel injection pressure from 180 bars to 200 bars resulted in decrease in smoke opacity and it was lowest at fuel injection of 200 bars. For Jatropha oil, lowest BSFC (0.3 kg kWh^{-1}) was found at 200 bars. Maximum thermal efficiency (31.71 %) was found at 200 bars at 72 per cent of rated load. Smoke opacity was also lowest at 200 bars which was 32 per cent. Based on BSFC, thermal efficiency and smoke opacity, 200 bars found optimum fuel injection pressure for Jatropha oil [13].

Raheman and Ghadge (2006) conducted a study on performance of compression ignition engine (Ricardo E6) with mahua (Madhuca indica) biodiesel and blends (B20, B40, B60, and B80). The heat content of pure B100 was lower than diesel by about 12 per cent so the mean BSFC for B20, B40, B60 B80 and B100 was higher than that of diesel by 4.3, 18.6, 19.6, 31.7 and 41.4 per cent, respectively. From the results it was concluded that B100 could be safely blended with diesel up to 20 per cent without significantly affecting the engine performance [14].

1.6.2 Review of literature of Emission characteristics

Peterson and Reece (1995) conducted test for a heavy duty pickup truck with turbocharged direct injection diesel engine. Rapeseed Methyl Esters (RME), Rapeseed Ethyl Esters (REE) alone and their blends with diesel were compared with diesel. The average of 100 per cent RME and 100 per cent REE reduced emissions of HC (52.4 %), CO (47.6 %), NO_X (10 %), and increased in CO_2 (0.9 %) and PM (9.98 %) compared to diesel. Also 100 per cent REE reduced HC (8.7 %), CO (4.3 %) and NO_X (3.4 %) compared to RME 100 per cent [15].

Moreno *et al.,* (1998) assessed the performance of an automobile diesel engine with various blends (0, 25, 50, 75 and 100 %) of sunflower methyl ester with diesel. The 22 per cent reduction in emission of hydrocarbon was obtained when using a mixture of 35 per cent sunflower methyl ester with diesel. As the percentage of sunflower methyl ester increased CO emission in the exhaust gases decreased (18 %) less than diesel. The minimum emission of NO_X (2.5 % less than diesel) was obtained with the percentage of sunflower methyl ester around 75 per cent[16].

Peterson *et al.*, (1999) conducted long term test on a heavy duty pick up diesel engine using a blend of 20 per cent Methyl Ester of Rapeseed oil (RME) and 80 per cent diesel for 161000 km. RME produced 5 per cent less power than diesel while 20 RME produced 1.5 per cent less power than diesel. Smoke density was 6.6 per cent higher than that of diesel. The average of 20 RME reduced emissions of HC (20 %), CO (25 %), NO_X (2.6 %) and PM (10.9 %) and there was in difference in CO_2 compared to diesel [17].

Kalligeros *et al.,* (2001) investigated the effect of marine diesel fuel on the exhaust emissions of a stationary diesel engine at different loads (Table 1.4).

They observed that as load on engine increases the NOx ppm, HC ppm and CO% are increases. the maximum values of these gases observed when engine is operated at 3.8Kw load.

The engine testing with the aim of obtaining comparative measures emissions such as CO, smoke density and NOx to evaluate the behavior of the diesel engine was performed by

(Raheman and Phadatare, 2004). Emission studies were carried out for different blends (B20, B40, B60, B80, B100 and diesel) at different loads (10, 25, 50, 75, 85 and 100 %).

Table 1.4 Emissions measurements from the stationary Peter engine when marine diesel fuel was used (base fuel measurements) at different loads

Engine load, kW	NOx, ppm	PM, mg m^{-3}	HC, ppm	CO, %
0.01	367	29	45	0.93
0.95	590	33.	44	1.03
1.90	793	60	46	1.55
2.85	823	125	50	1.45
3.80	1014	138	53	2.00

They observed that the minimum and maximum CO produced using B20 to B100 were 0.004 and 0.016 per cent, resulting in a reduction of 94 per cent and 73 per cent, respectively. The minimum and maximum smoke densities produced were 1 per cent and 3 per cent with a maximum and minimum reduction of 80 and 20 per cent. The amount of NOx produced for B20 to B100 varied between 4 and 12 ppm as compared to 12 and 13 ppm for diesel. On an average, 26 per cent reduction in NOx was obtained for biodiesel and its blends as compared to diesel. In case of exhaust gas temperature, there was no much variation between blends and diesel [18].

Puhan and Vedaraman (2004) have tested a diesel engine with Mahua oil methyl ester and its blends with diesel and found a decrease in emissions of CO, hydrocarbon, smoke number and oxides of nitrogen by 30, 35, 11, and 4 per cent, respectively as compared to diesel [19].

Labeckas and Slavinkas (2004) evaluated the combustion efficiency, emission composition and smoke opacity of the exhaust using diesel and shale oil. The total nitrogen oxide emissions from the shale oil at engine partial load remain lower although when running at the maximum torque and rated power, the NOx emissions became correspondingly higher by

21.8 and 27.6 per cent. The smoke opacity of the fully loaded engine at a wide range of speeds was lower by 30-35 per cent, whereas the carbon monoxide and unburned hydrocarbon emissions in the exhaust at moderate and full load regimes did not undergo significant changes [20].

Knothe *et al.,* (2005) compared three fatty acid methyl ester, methyl laurate, methyl palmitate and methyl oleate with neat dodecane and hexadecane as well as commercial samples of biodiesel and petro-diesel for exhaust gas emission in a heavy-duty six-cylinder diesel engine (Table1.4) [21].

Hess *et al.,* (2006) investigated two routes to reformulate Soya based biodiesel in an effort to reduce nitrogen oxide emissions. The NOx emission were examined using a Yanmar L100 single cylinder, four stroke, naturally aspirated, air cooled, direct injection diesel engine. Using either isomerized methyl oleate or iosomerized soy biodiesel, at 20 per cent blend level in diesel, nitrogen oxide emissions were increased by between1.5 and 3 per cent, but decreased about 5.7 per cent with 20 per cent polyol biodiesel in petro-diesel. It was concluded that polyol functionality has a NOx reducing effect on emission [22].

Table 1.5 Exhaust emissions of tested fuels

Fuel	**Exhaust emissions, Kg kWh^{-1}**			
	HC	**CO**	**NOx**	**PM**
Petro-diesel	0.04	0.39	1.69	0.08
Methyl soyate	0.02	0.29	1.67	0.01
Methyl oleate	0.02	0.20	1.79	0.02
Methyl palmitate	0.03	0.22	1.61	0.01
Soyabean Biodiesel	0.02	0.33	1.55	0.05
Methyl laurate	0.03	0.23	1.47	0.009
Hexadecane	0.01	0.29	1.42	0.04
Dodecane	0.04	0.33	1.43	0.04

1.7 PONGAMIA AS SOURCE OF ENGINE FUEL

Pongamia pinnata (Linn) is fast-growing leguminous tree with the potential for high oil seed production and the added benefit of the ability to grow on the marginal land. These properties support the suitability of this plant for large scale vegetable oil production required by a sustainable biodiesel industry.

At a time when society is become increasingly aware of the decline reserves of oil for the production of fossil fuels, it has become apparent that biofuels are destined to make a subsustantial contribution to the future energy demands of the domestic and industrial economies.

The use of vegetable oil from plants such as karanja has the potential to provide an environmentally acceptable fuel, the production of which is greenhouse gas neytral, with reduction in current diesel engine emissions.

RREFFEPaul T. Scott et al. "pongamia pinnata: An untrapped resource for the biofuels industry of the future" year 2008 page no 7.

1.8 OBJECTIVE OF STUDY

The main objectives of the present study are given as follows:

i. Karanja (Pongamia pinnata) oil, a non-edible high viscosity straight vegetable oil, was blended with conventional diesel in various proportions to evaluate the performance and emission characteristics of a single cylinder direct injection constant speed diesel engine.

ii. Diesel and karanja oil fuel blends (5%, 10%, 15%, and 20%) were used to conduct short-term engine performance and emission tests at varying loads (0%, 20%, 40%, 60%, 80%, and 100%).

iii. Tests were carried out over the entire range of engine operation and engine performance parameters such as fuel consumption, thermal efficiency, exhaust gas temperature, and exhaust emissions (smoke, CO, CO2, HC, NOx, and O2) were recorded.

iv. The brake specific energy consumption (BSEC), brake thermal efficiency (BTE), and exhaust emissions were evaluated to determine the optimum fuel blend.

1.9 OUTLINE OF THESIS

There are five chapters of thesis, first chapter i.e. introduction includes the energy scenario of the world as well as of India, renewable energy potential of India, biomass energy, vegetable oil, literature reviews and objective of present thesis. The second chapter i.e. the straight vegetable oil which includes the vegetable oil resources, advantages and limitation of SVO as engine fuel. Transterifiacation of SVO limitation of SVO as a fuel, biodiesel production from SVO, engine modification to use SVO as engine oil. third chapter consist of the general information regarding the pongamia pinnata(karanja oil) . fourth chapter consists of the experimental set up, experimental procedure. And last chapter consist of the results and discussion it includes performance study, emission study.

1.10 OUTCOME OF THESIS

We have studied the performance evaluation of diesel engine under different loading condition for various blends B5,B15,B20 and B30 and it is compared with the convectional diesel fuel we have also measured the exhaust gases emitted from the engine under the same conditions, we concluded the following results :

1) The B10 sample have maximum break thermal efficiency under the 60%-80 % loading which is equivalent to convectional diesel fuel
2) The BSFC for all the blends is slightly less than the diesel fuel so it can be possible to operate diesel engine for lower blends upto B15 for 60% to 80% loading condition of the engine.
3) The exhaust gases emitted from all the blends is slightly less than diesel fuel for the full operation of engine from no load to full load.

CHAPTER- 2

STRAIGHT VEGETABLE OILS

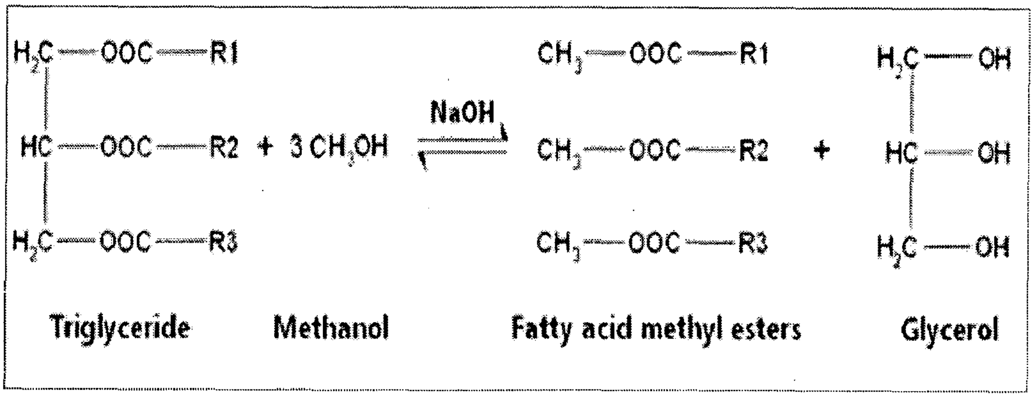
2.1 GENERAL

India has vast amounts of wasteland that government agencies and other non-government organizations are using for cultivation of non-edible oil seeds, fire, and fuel wood species for economic as well as environmental benefits. Among the non-edible oil species, Karanja, Neem, Jatropha, and Mahua are the prominent trees. The non-edible oil is being used in the soap and pharmaceutical industries, but due to the dark colour and odour of karanja oil, it is less preferable compared to other non-edible oil species. Hence, karanja oil can be obtained easily for engine applications. The experiments were conducted on a single-cylinder constant speed (1500 rpm) diesel engine having compression ratio 17.5, as widely used in rural/agricultural applications. The fuels studied were mineral diesel and blends of KVO with mineral diesel. The most predominant oil bearing crops considered as fuel substitutes are as follows:

Sunflower, safflower, soybean, cotton, winter rape, canola, and peanut the fuel properties can been be improved with some methods of modification such as blending, micro emulsification

2.2 TRANSESTERIFICATION OF VEGETABLE OILS

In this process, a triglyceride (vegetable oil) reacts with an alcohol in the presence of a strong acid or base to produces alkyl esters of fatty acid and glycerol. The overall process consists of three consecutive reversible reactions, in which di-and monoglycerides are formed as intermediates Stoichiometric mole of triglyceride requires [3] mole of the alcohol and produce three mole alkyl esters and one mole of glycerol as shown in fig 2. The excess alcohol is used to increase the yield of the alkyl esters and allow its phase separation from the glycerol. The factors like types catalyst (alkali or acid), alcohol vegetable oil molar ratio, temperature purity of the reactants free fatty acid acid contains have been found to have significance influence on the rate of reaction.



R1=R2=R3= different fatty acid molecules

Figure 2.1 Stoichiometric transesterification reactions

2.3 LIMITATION OF STRAIGHT VEGETABLE OIL AS ENGINE FUEL

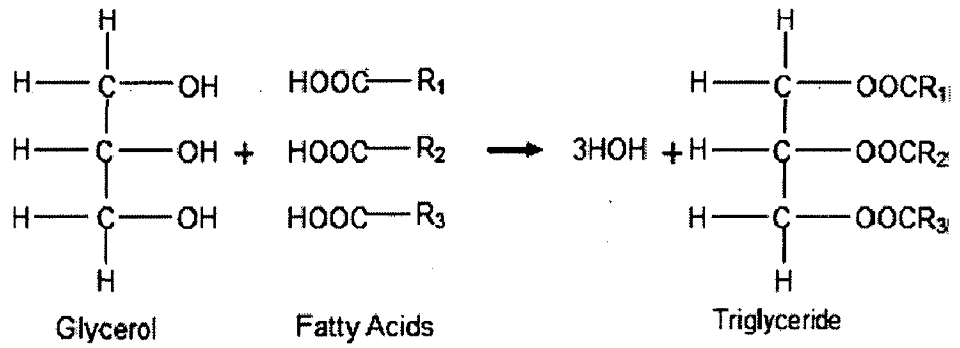
The following are the limitation of straight vegetable oil as engine fuel

i. Straight vegetable oils (SVOs) have been tested in diesel engines. The relatively high viscosities (11–17 times higher than diesel) of these oils cause problems such as coking of the injectors, oil ring sticking, and thickening of the lubricating oil.

ii. This high viscosity results from the high molar masses of the oils and the presence of unsaturated fatty acids.

iii. At high temperatures there can be certain problems due to polymerization of unsaturated fatty acids. This occurs when cross-linking starts to occur between molecules, causing the formation of very large agglomerations and consequent gumming.

iv. Commercial diesel chemical composition is the mixture of alkanes, alkenes, alkynes, and small traces of sulphur. Diesel has more number of double bonds than vegetable oils. If we study the structure of a typical triglyceride (vegetable oil), there are only three double bonds as shown below.



v. The use of SVOs as a fuel for compression ignition engines is restricted by certain unfavorable properties, particularly their viscosity, the higher viscosities of SVOs cause poor fuel atomization, which leads to incomplete fuel combustion and carbon deposition on the injector and valve seat, resulting in serious engine fouling.

vi. When direct injection engines are run with SVOs, injectors become choked after a few hours. This choking also leads to poor fuel atomization and incomplete combustion. Due to incomplete combustion, partially burnt vegetable oil runs down the cylinder walls and dilutes the lubricating oil.

2.4 BIODIESEL PRODUCTION FROM STRAIGHT VEGETABLE OILS

Keeping in view the difficulties being faced during the use of SVO in engines, one major problem is the higher viscosity. The triglycerides as present in vegetable oil can be modified by transesterification to impart fuel properties similar to diesel, thus making, its suitability for use in engines. The selection of appropriate technology for production of biodiesel calls for careful selection of processing steps. Various methods for the modification of SVO are categorized as: (i) Pyrolysis (ii) Micro-emulsification (iii) Transesterification (iv) Supercritical Methanol method. The Fig. 2.2 gives the overall schematic of various processes for modification of vegetable oils to biodiesel.

Among the method given in flow chart, the transesterification method has been found of immense significance to simplicity & is discussed in paper.

Ulf Schuchardta, Ricardo Serchelia, and Rogerio Matheus Vargas: Transterification vegetable ois : a Review J.Braz. hem.Soc., 9(1), 199-210(1998) [23].

2.5 ENGINE MODIFICATIONS TO USE SVO AS ENGINE FUEL

Despite the above-mentioned limitations of SVOs, it could be possible to use them for certain low-end applications, such as energizing the single cylinder diesel engines which are widely used in rural/agricultural applications. However, this would call for an additional fuel supply, since starting and stopping of the engine has to be done on diesel only to avoid deposition of neat oil on various engine parts, which would affect cold starting and performance of the engine. Also, the exhaust heat of the engine could be utilized to reduce the viscosity of the intake oil through an appropriate heat exchange device. Experiments conducted at various institutes have concluded that engines running on neat SVOs with the integration of above-mentioned additional sub-systems could perform effectively for around 250 h

CHAPTER- 3

PONGAMIA PINNATA (KARANJA)

3.1 GENERAL

Pongamia Pinnata trees are normally planted along the highways, roads, 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, few million tons of oil will be available for Lighting the Lamps in rural area. It is the best substitute for Kerosene. There are nearly 30,000 square km of water reservoirs in India. This tree can be cultivated in our water storage reservoirs up to 1.5 meters depth and reap additional economic value from unused reservoir land. It is one of the few nitrogen fixing trees (NFTS) to produce seeds containing 30-40% oil. It is often planted as an ornamental and shade tree. This species is commonly called pongam, karanja, or a derivation of these names.

3.1.1 BOTANY

Pongamia *(Leguminasae)*. In India the most of the variety of Pongamia is found of P. Pinnata (Linn) family. Pongamia is also called *Punnu* in Malyalum, *Pungu* in Tamil and *Kranuga* in Telagu.[2]

Pongam (Leguminoceae, subfamily Papilionoideae) is a medium sized tree that generally attains a height of about 8 meters and a trunk diameter of more than 50 cm. The trunk is generally short with thick branches spreading into a dense hemispherical crown of dark green leaves. The bark is thin gray to grayish- brown, and yellow on the inside. The tap root is thick and long, lateral roots are numerous and well developed.

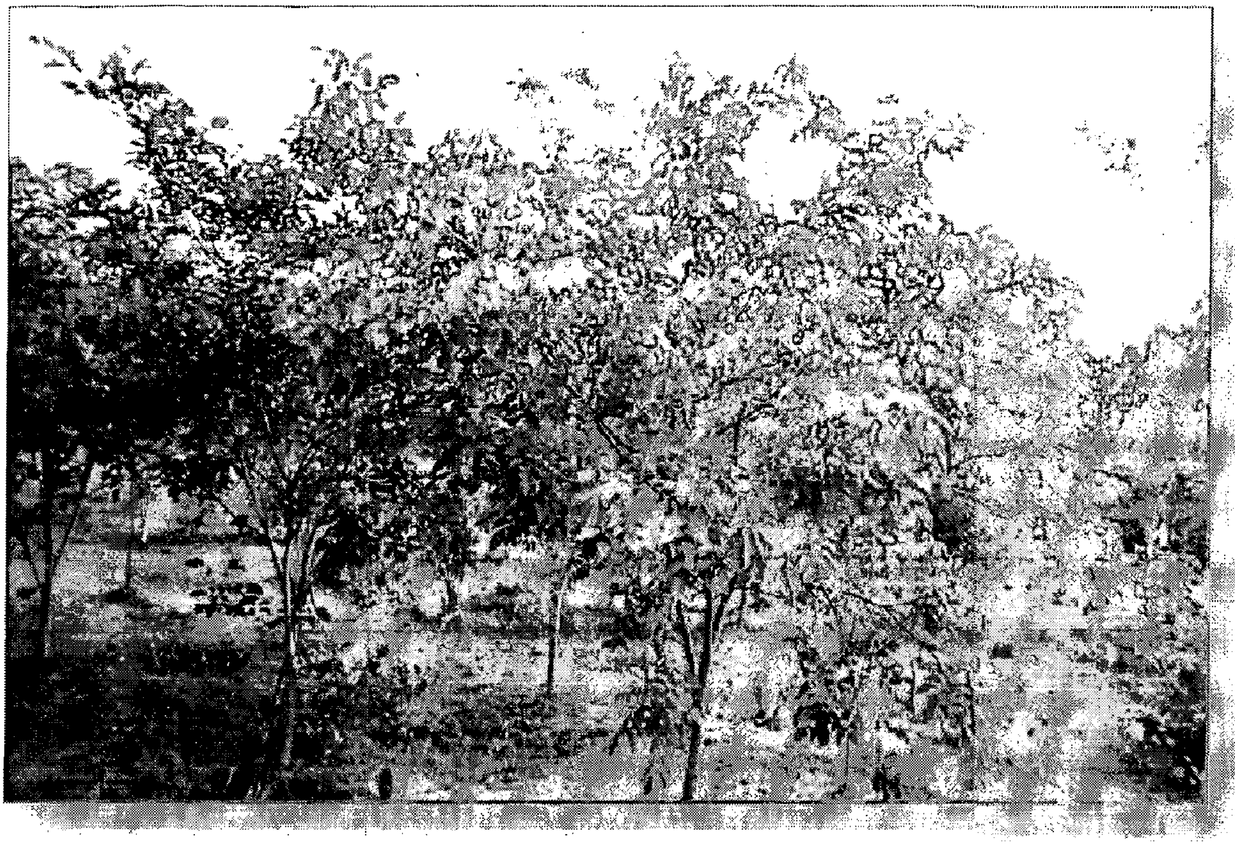


Figure 3.1 karanja plant

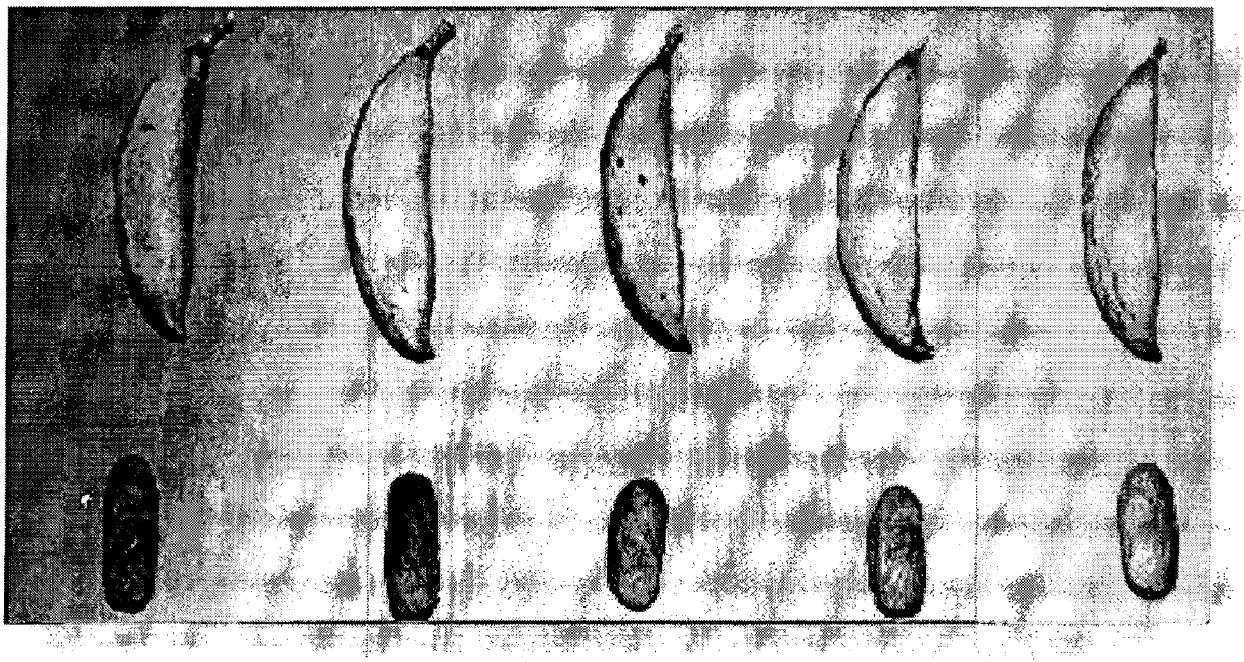


Figure 3.2 Seeds of karanja plant

The alternate, compound pinnate leaves consist of 5 or 7 leaflets which are arranged in 2 or 3 pairs, and a single terminal leaflet. Leaflets are 5-10 cm long, 4-6 cm wide, and pointed at the tip. Flowers, borne on racemes, are pink, light purple, or white. Pods are elliptical, 3-6 cm long and 2-3 cm wide, thick walled, and usually contain a single seed. Seeds are 10-20 cm long, oblong, and light brown in color.

3.2 ECOLOGY

Native to humid and subtropical environments, pongam thrives in areas having an annual rainfall ranging from 500 to 2500 mm. in its natural habitat, the maximum temperature ranges from 27 to 38oC and the minimum 1 to16oC. Mature trees can withstand water logging and slight frost. This species grows to elevations of 1200 m, but in the Himalayan foothills is not found above 600 m. Pongam can grow on most soil types ranging from stony to sandy to clay, including Verticals. It does not do well on dry sands. It is highly tolerant of salinity. It is common along waterways or seashores, with its roots in fresh or salt water. Highest growth rates are observed on well drained soils with assured moisture. Natural reproduction is profuse by seed and common by root suckers.

3.3 DISTRIBUTION

The natural distribution of pongam is along the sea coasts and river banks in India and some forest localities. Native to the Asian subcontinent, this species has been introduced to humid tropical lowlands in the, Malaysia, Australia, the Seychelles, the United States and Indonesia.

3.4 ADVANTAGES OF KARANJA PLANTATION

They can be describing as:

3.4.1 Wood

Pongam is commonly used as fuel wood. Its wood is medium to coarse textured. However, it is not durable, is susceptible to insect attack, and tends to split when sown. Thus the wood is not considered a quality timber. The wood is used for cabinet making, cart wheels, posts, agricultural implements, tool handles and combs.

3.4.2 Oil:

A thick yellow-orange to brown oil is extracted from seeds. Yields of 25% of volume are possible using a mechanical expeller. However, village crushers average a yield of 20% (ICFRE, undated). The oil has a bitter taste and a disagreeable aroma, thus it is not considered edible. In India, the oil is used as a fuel for cooking and lamps. The oil is also used as a lubricant, water-paint binder, pesticide, and in soap making and tanning industries. The oil is known to have value in folk medicine for the treatment of rheumatism, as well as human and animal skin diseases. It is effective in enhancing the pigmentation of skin affected by leucoderma or scabies (ICFRE undated). The oil of Pongam is also used as a substitute for diesel. Oil from seeds useful in cataneous affections.

3.4.3 Fodder and feed

Opinions vary on the usefulness of this species as a fodder .The leaves are eaten by cattle and readily consumed by goats. However, in many areas it is not commonly eaten by farm animals. Its fodder value is greatest in arid regions. The oil cake, remaining when oil is extracted from the seeds, is used as poultry feed.

3.4.4 Other uses

i. Dried leaves are used as an insect repellent in stored grains.

ii. The oil cake, when applied to the soil, has pesticidal value, particularly against nematodes and also improves soil fertility.

iii. Seeds and roots used as fish poison.

iv. Fresh bark used internally in bleeding piles.

v. Leaves in form of a poultice applied to ulcers infested with worms.

vi. Herpes and scabies used in rheumatism.

vii. Juice of the roots used for closing fish tulous sores and for cleaning foul ulcers; given internally with equal quantities of coconut milk and lime water for gonor [1] & [2].

3.5 PLANTATION

Pongam is often planted in homesteads as a shade or ornamental tree and in avenue plantings along roadsides and canals. It is a preferred species for controlling soil erosion and binding sand dunes because of its dense network of lateral roots. Its root, bark, leaf, sap, and flower also have medicinal properties.

3.5.1 Agro-practices

Sowing and Germination: Pongam is easily established by direct seeds or by planting nursery-raised seedlings or stump cuttings of 1-2 cm root-collar diameter. In peninsular India, the seeding season is April to June, and the seed yield per tree ranges from about 10 kg to more than 50 kg. There are 1500-1700 seeds per kg. Seeds, which require no treatment before sowing, remain viable for about a year when stored air-tight containers. Seed germinates within two weeks of sowing. Seedlings attain a height of 25-30 cm in their first growing season.

3.5.2 Transplantation

Transplanting to the field should occur at the beginning of the next rainy season when seedlings are 60 cm in height (GOI 1983). Seedlings have large root systems. Soil should be retained around the roots during trans plantation. The spacing adopted in avenue plantings is about 8 m between plants. In block planting, the spacing can range from 2 x 2 to 5 x 5 m. Pongam seedlings withstand shade very well and can be inter planted in existing tree stands.

3.6 MANAGEMENT

Pongam should be grown in full sun or partial shade on well-drained soil. A relatively low maintenance tree once established, is resistant to high winds and drought but is susceptible to freezing temperatures below 0o C. Pongam will show nutritional deficiencies if grown on soil with a pH above 7.5. Space major limbs along the trunk to increase the structural strength of the tree. Keep limbs less than two-thirds the diameter of the trunk to help ensure that branches are well secured to the tree.

3.6.1 Pests

No pests are of major concern, but caterpillars occasionally cause some defoliation.

3.6.2 Diseases

No diseases are of major concern.

3.7 YIELD OF SEEDS, OIL AND COST OF PRODUCTION

From 5th year onwards minimum seed yield will be 20 kg per plant and total benefit will increase over the years and stabilized at 20 years. The normal life period of karanja plant is 40-45 years approximately the yield of seed, oil and cost of plantation are given below:

i. Seed yield per hectare = 1.2 tons/year
ii. karanja oil per hectare = 0.35 tons/year
iii. cost of production of karanja plan per year = 15000/ha

After five years the maintenance cost of karanja plant per year is very less which mainly consist of the weeding, fertilizer application only

3.8 TRANSPORTATION OF KARANJA OIL

Demand for transport fuel is increasing unabatedly in India. . On the other hand there are frequent hikes of prices of fossil fuel and uncertain supply in international market. To minimize the import of crude oil we must go for Bio fuels which are renewable and eco friendly. Pongamia oil may stands as Bio-diesel which is renewable, safe and non-polluting. It holds great promise to the rural sectors of North East India to meet the energy and organic fertilizer requirements. Of course researchers are to be carried out on Pongamia to standardize agro-technology , low cost and efficient mechanical device to expel oil , to find out the economics, high yielding and high oil content varieties suitable to the different agro-climates of North East India. In that way researchers are also to be carried out value addition on by products of Pongamia oil. By planting Pongamia on roadsides, river bank, on the two sides of irrigation canals, marginal and degraded soils. . N.E. India will able to produce tons of Bio-diesel and organic fertilizers (Oil cake) in near future

3.9 EXTRACTION OF KARANJA VEGETABLE OIL

Karanja seeds were obtained from Maharashtra, India and the oil was extracted from the kernel by mechanical expeller, Soxhlet extraction and cold percolation. In the process of mechanical expression, a screw press oil expeller was used. For cold percolation and Soxhlet extraction, the kernels were crushed using a mechanical blender. In cold percolation method, 200ml of *n*-hexane was added to 100 g of the crushed kernel in a Xask and kept overnight. In Soxhlet extraction procedure, 50 g of crushed kernel was packed in a thimble and the oil was extracted with *n*-hexane for 2h. In both, cold percolation and Soxhlet extraction methods, the oil was isolated from *n*-hexane by rotary evaporator (Laborata 4000-EYcient, Heidolph Instruments).

The oil after mechanical extraction was subjected to Wltration and neutralization. The acid value of the mechanically extracted oil was 5.06mg KOH/g and neutralized by using appropriate amount of potassium hydroxide to reduce the acid value to 0.6mg KOH/g. Karanja oil extracted by screw press expeller was altered by using muslin cloth with 10–15 _m pore size. The apparatus used for transterification consisted of oil bath, reaction Xask with condenser and digital rpm controlled mechanical stirrer. The volume of the glass reactor capacity was 1 l and consisted of three necks, one for stirrer, and the others for condenser and inlet for the reactants. A digital temperature indicator was used to measure the reaction temperature. The batch reactor had a valve at the bottom for collection of the Wnal product. Karanja oil (200ml) was preheated to the desired temperature before starting the reaction. The potassium hydroxide–methanol solution was prepared freshly in order to maintain the catalytic activity and to prevent moisture absorbance. The methanolic solution was added to Karanja oil in the reaction Xask and the measurement of time was started at this point. At proper spaced interval of time, 50 _l of the reaction mixture were withdrawn from the reaction vessel and diluted up to 20 times with HPLC grade methanol, which was analyzed by high performance liquid chromatography.[8].

3.10 BIODIESEL PRODUCTION FROM PONGAMIA OIL

Untreated karanja oil is mixed with a mixture of anhydrous methanol and a catalyst (NaOH) in proper proportion. The mixture is maintained at a temperature little below 650C (being the B.P of methanol) and continuously stirred the mixture for around three hours. After completion of stirring, the mixture is allowed to settle down for 24 hours. The layer of glycerol settled at the bottom is carefully taken out and the upper layer is the ester of karanja oil which is tapped separately.

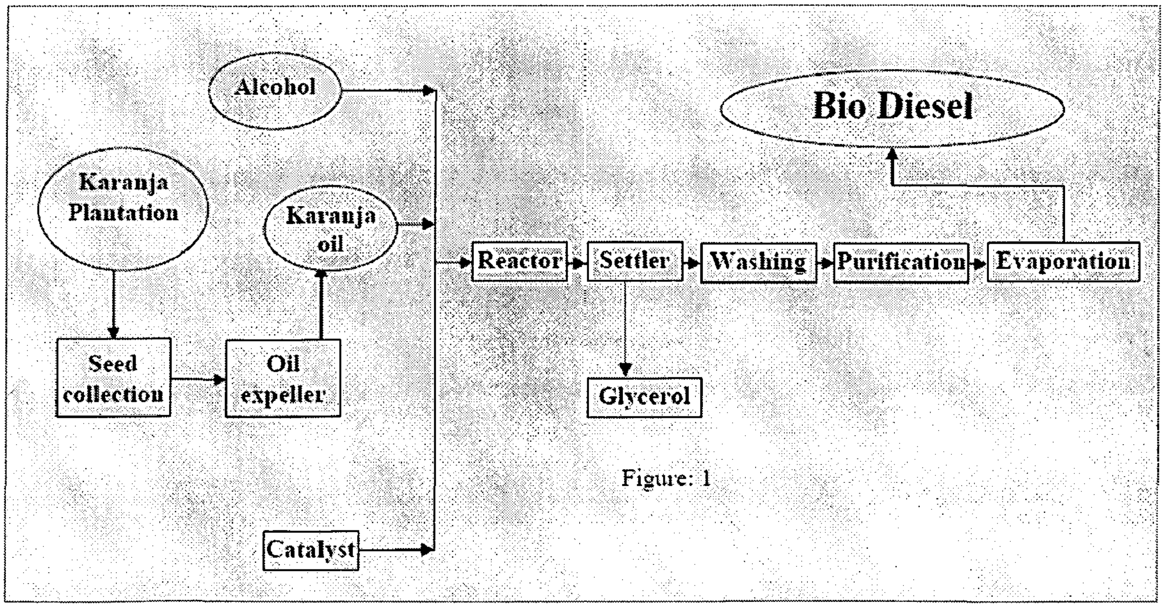


Figure 3.3 Biodiesel productions from pongamia oil

3. 11 FUEL PROPERTIES OF KARANJA OIL

Table 3.1 Physical and chemical properties of karanja oil

Sample	Specific Gravity at 30°C	kinematic viscosity (cSt) at 30°C	calorific value in kJ/Kg
disel	0.83	3.2	42000
B5	0.8298	3.84	41500
B10	0.8328	4.83	41302
B15	0.8375	5.41	41218
B20	0.8399	6.15	41143
B30	0.8507	7.42	40032
karanja oil	0.9236	15.8	37305

3.12 CHEMICAL PROPERTIES OF KARANJA OIL

properties	Karanja oil	diesel
Carbon residue (%)	0.71	0.1
Ash content (%)	0.04	0.01
Sulphur content (%)	-	0.05

3.13 FREE FATTY ACID COMPOSITION OF KARANJA OIL

FFA	Percentage (%)
Palmitic acid	11.25
Stearic acid	7.5
Oleic acid	51.59
Linoleic acid	16.64

CHAPTER-4

PERFORMANCE EVALUATION OF DIESEL ENGINE

4.1 GENERAL

Performance evaluation of a physical diesel generating set using blends of SVO with diesel/ methanol, blends of biodiesel with diesel fuel has been carried out with respect to efficiency and brake specific fuel consumption (BSFC) under variable load conditions. The results are reported in this chapter.

4.2 EXPERIMENTAL SETUP

A schematic of experimental is shown in fig.4.1 consisting of following components which are discussed as:

4.2.1 Diesel engine

The kirloskar make single cylinder diesel engine-generating set of 2 kVA rating was used for experimentation. The technical details of engine are given in table 4.1.the filter unit of the diesel engine was disconnected from its diesel tank and connected directly to fuel measuring unit.

4.2.2 Generator

A single-phase synchronous generator directly coupled with diesel engine was used. The technical specification of generator is given in table 4.2.

4.2.3 Resistive type load panel

The resistive type load panel was fabricated which was equipped with voltmeter, current meter, wattmeter, and energy meter. The loading capacity of this panel kept as 2.5 kW. A photograph of complete experimental setup is shown in the fig.4.2.

4.2.4 Fuel measurement unit

The fuel measurement unit consists of graduated transparent glass cylinder. The cylinder was attached to wood stand as shown in fig.4.2. The top end of the cylinder was open and bottom end was fitted with stopcock. The outlet of stopcock was connected to the filter unit of the diesel engine by a PVC pipe. A schematic of the experimental set up is given in fig. 4.1 and photograph in fig.4.2.

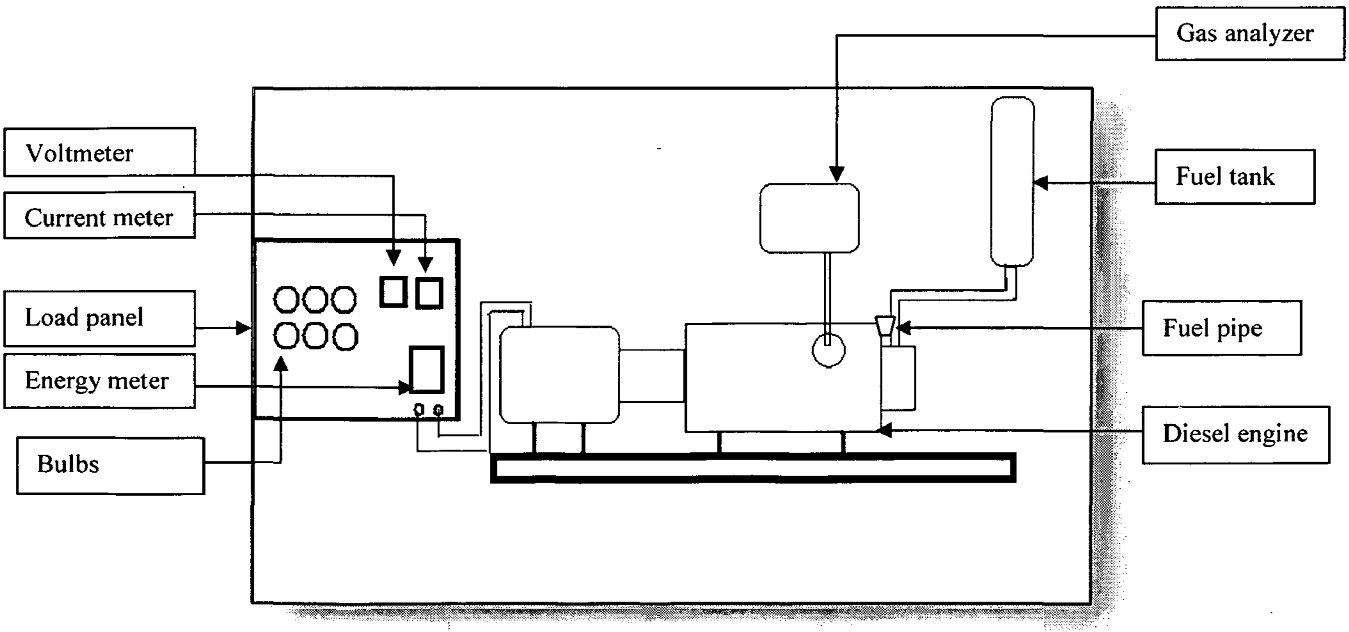


Fig 4.1: Schematic of Experimental Setup

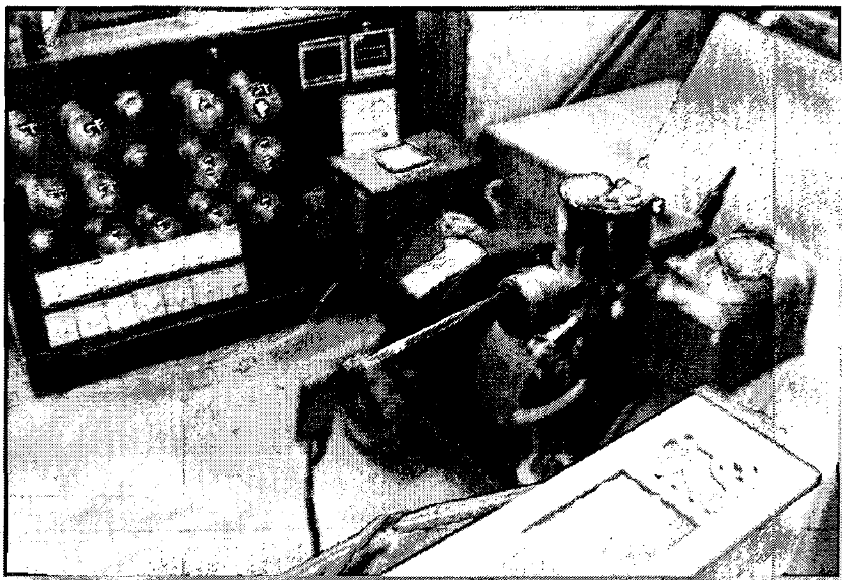


Fig 4.2: Engine Setup for Performance Testing

Table 4.1: Diesel Engine Specification Used in Experimentation

S.No.	Parameters	Details
1	Make and model	Kirloskar, AA35
2	Type of engine	Vertical, 4-stroke, single acting high speed compression ignition diesel engine
3	No of cylinder	1
4	Rating @ 1500 rpm	2.6 kW (3.5 bhp)
5	Base	30 mm
6	Stroke	76 mm
7	Cubic capacity	0.382 liters
8	Compression ratio	15.6: 1
9	Duel timing for standard engine by spill (BTDC)	24^0
10	BMEP @ 1500 rpm	5.5 kg/mm^2
11	Rated speed	1500 rpm

12	Direction of rotation	Clockwise when looking at fltwheel end
13	Inlet valve open BTDC	4.5^0
14	Inlet valve closes @ ABDC	35.5^0
15	Exhaust valve opens @ BBDC	35.5^0
16	Exhaust valve closes ATDC	4.5^0
17	Governor type	Mechanical, centrifugal type
18	Nozzle opening pressure	190-210 kg/cm^2
19	Fuel oil tank capacity	3.75 liters
20	Lube oil sump capacity	1.3 liters

Table 4.2: Specification of Generator Used in the Experimentation

S.No.	**parameters**	**Values**
1	Make	Kirogen alternator single phase
2	Model	KBM-102
3	Output	2 kVA
4	Voltage	200 V
5	Current	8.7 Amp.
6	Power factor	1
7	Frequency	50 Hz.
8	RPM	1500

4.3 PARAMETERS MEASURED

The parameters measured during the experimentation are fuel consumption, load, voltage, current and energy

4.4 INSTRUMENTATION

Various instruments used are discussed as below:

4.4.1 Fuel measurement

During the fuel measurement, the gradual lowering of fuel level was observed in the specified time during the run of engine. The least count of fuel measurement unit is 1ml. the fuel consumption at a particular load at a given time has been calculated.

4.4.2 Load measurement

The wattmeter (Model SR-144-1E-IPWM20A) has the least count of 100W. Before taking the reading, the deflection needle was set at zero position. During the run of engine, the current deflection shown by needle was taken as load operated on generator.

4.4.3 Voltage measurement

Digital voltmeter was used to show the voltage of generator during the engine operation. The least count was 1 V.

4.4.4 Energy measurement

Energy meter was AC single-phase 2 wire static kWh meter. The least count of energy meter was 0.1kWh. The cumulative reading of energy generated in unit has been shown by energy meter. For the value of energy generated for a fuel in the specified time, the current cumulative reading was obtained by subtracting from the p [previous cumulative reading.

4.5 EXPERIMENTAL PROCEDURE

The diesel engine is directly coupled with 2kVA alternator and loaded by electrical resistance. A separate fuel measurement unit is connected with engine. A resistive load panel is also attached with the output of the generator.

The engine- generator set is run initially using diesel for 10 minutes at each part load of 20% 40%, 60% 80% and 100% of 2 kW respectively. In each case, the rpm of the generator is maintained at 1500 rpm.

The karanja oil is first heated in water bath at 100°C temperature for 6 hours. The main objective of heating the oil is to remove the moisture content. Different blends from Karanja oil with diesel were prepared and are named B5, B10, B15, B20 and B30. Before using blend, each blend is mixed thoroughly with magnetic stirrer for 15 minutes. The various properties such as fuel properties, chemical properties, thermo gravimetric analysis of karanja oil and its blend with diesel fuel are then measured.

These blends of Karanja oil with diesel fuel is then tested in diesel engine which is coupled with 2kW alternators, during each blend, the filter of diesel engine was opened and complete blend was drained so that it could not impure next blend by mixing with its previous blend. Then again for another blend, in the similar fashion, the experiment was repeated for knowing the above stated parameters. Engine performance and its emission gaseous are also evaluated for different blend of karanja oil with diesel in the similar fashion as stated above. In this way continuously for one month, the experimentation was performed for all type of blends as stated above.

The fuel consumption at each case is measured by using stopwatch. At the same time the reading of voltmeter, current meter and energy meter are also noted down.

CHAPTER-5

RESULTS AND DISSCUSION

The results of the investigation carried out for the measurement of the characteristics of karanja oil and its blend with diesel, the engine performance and exhaust emission studies using blends of karanja oil as discussed in this chapter in the following subheading:

1. Performance of engine with blends of karanja oil with diesel.
2. Effect of blends of karanja oil and diesel on exhaust emissions of engine

5.1 PERFORMANCE OF ENGINE WITH BLENDS OF KARANJA OIL WITH DIESEL

The engine performance if karanja vegetable oil and its blend with diesel fuel are tested on 2KVA diesel generator. The BTE and BSFC measured under various loading of engine which is measured with the help of load resistive panel attached with diesel engine alternator which are explained as below:

5.1.1 Variation of Brake thermal efficiency (BTE) Vs the load

The variation of BTE against the different load at electrical load panel attached with diesel alternator for diesel fuel and the different blends of karanja oil with diesel fuel are as shown in figure 5.1.1

Brake thermal efficiency (BTE) is the ratio of brake power to the fuel energy. It assumes greater importance because it is ultimately the brake power that is available as the useful energy, which is of concern to the most. The efficiency of any engine depends upon the physical processes involved such as atomization, evaporation, combustion temperature, etc. which in turn governed by the type of fuel used and the engine parameters like compression ratio, injection timing, load etc.

In all the tests, brake thermal efficiency was increased with the increase in load. BTE for diesel and blends of karanja oil with diesel increased with increase in load from no load to full load condition 2kw load, this was due to reduction in heat loss and increase in brake power

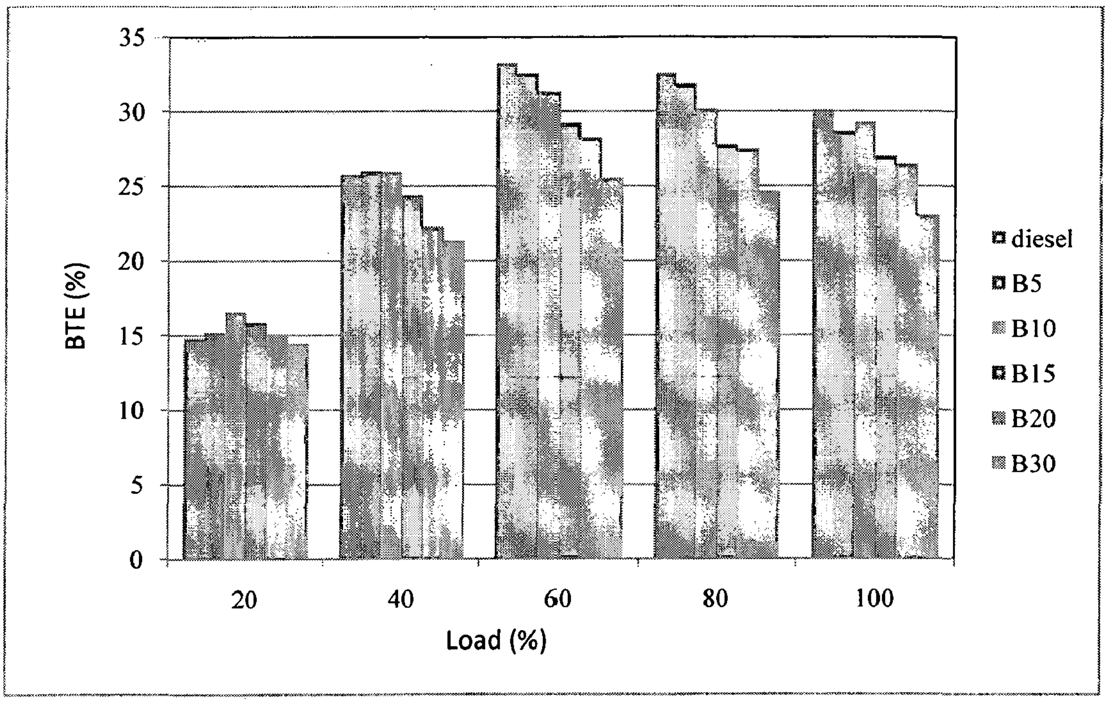


Figure 5.1 Variation of brake thermal efficiency Vs loads for different blends of karanja oil

with increase in load. In case of diesel, the BTE was higher (33.28 %) at 60% loading condition after that it reduces slightly up to full loading condition of engine. This may be due to the high fuel consumption which results in incomplete combustion of fuel. The same result has been obtained for B5, B10, B15, B20 and B30 but brake thermal efficiency was lower i.e. 32.55%, 31.37%, 29.26%, 28.24% and 25.59% as compared to diesel due to slightly higher density and lesser calorific value of blends.

5.1.2 Variation of Brake Specific fuel Consumption against the Load

The variation of BSFC against the different load at electrical load panel attached with diesel alternator for diesel fuel and the different blends of karanja oil with diesel fuel are as shown in figure 5.1.2 to figure 5.1.7:

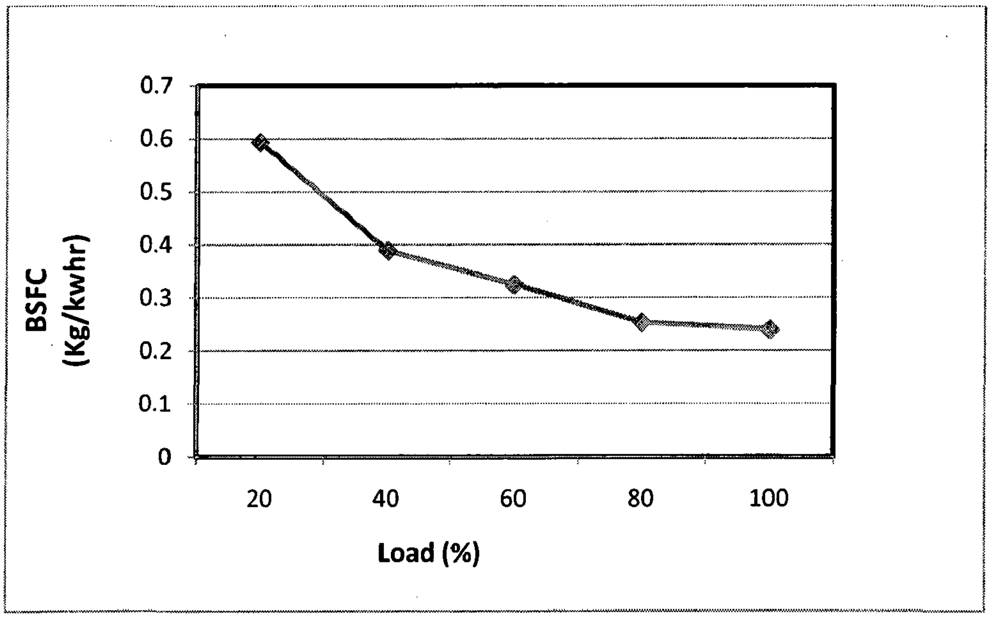


Figure 5.2 Variation of brake specific fuel consumption against the load for diesel

In case of diesel, BSFC was decreased from 0.5935 to 0.2402 for with respect to increase in load from no load to 2kw. The reason for this reduction could be due to higher percentage of increase in brake power with load as compared to fuel consumption. Ramadhas *et al.*, (2004) also observed same trend of BSFC for rubber seed oil and was also decreased with increase in load (0.744 to 0.435 kg kWh^{-1}).

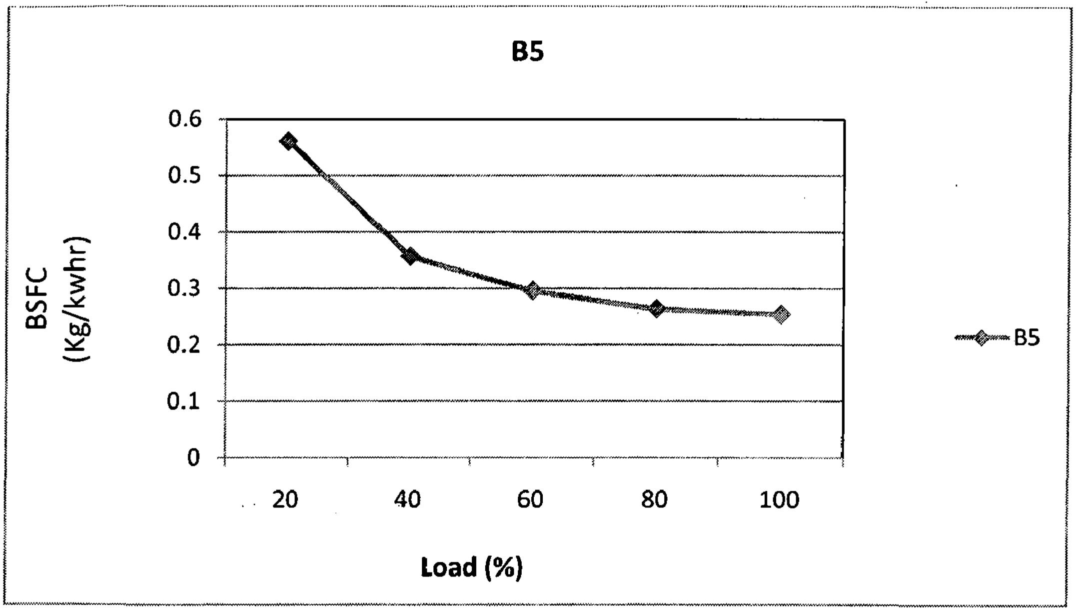


Figure 5.3 Variation of brake specific fuel consumption against the load for diesel

In case of B5, BSFC was decreased from 0.5619 to 0.2538 for with respect to increase in load from no load to 2kw. The reason for this reduction could be due to higher percentage of increase in brake power with load as compared to fuel consumption the BSFC was decreases slightly from 60% to full load condition

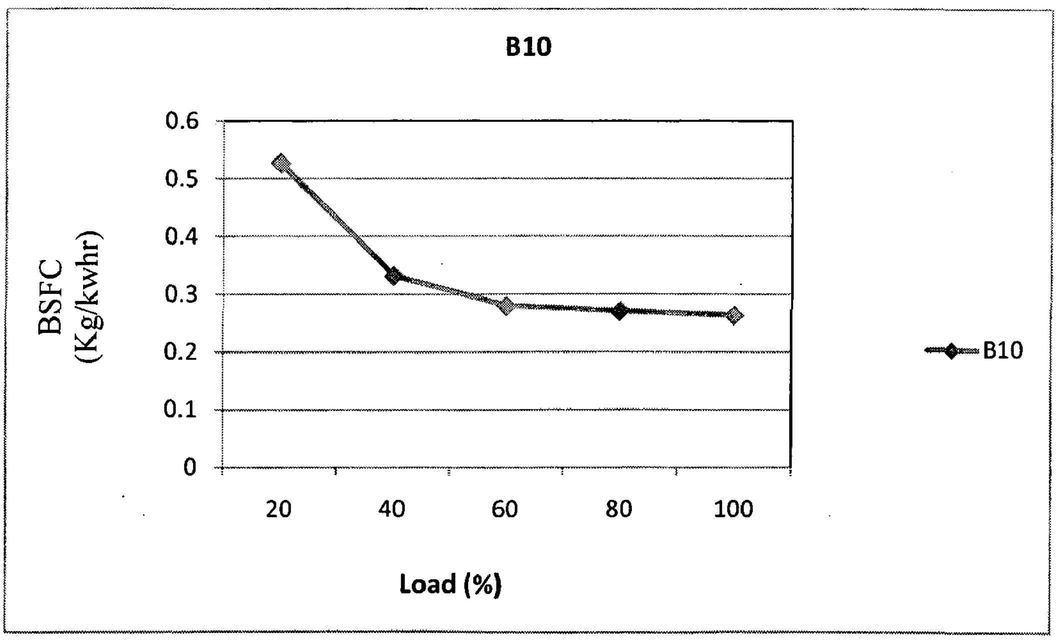


Figure 5.4 Variation of brake specific fuel consumption against the load for diesel

In case of B10, BSFC was decreased from 0.5271 to 0.2636 for with respect to increase in load from no load to 2kw. The BSFC was decreases slightly after 40% up to full load condition as compare to the Diesel and B5 blend.

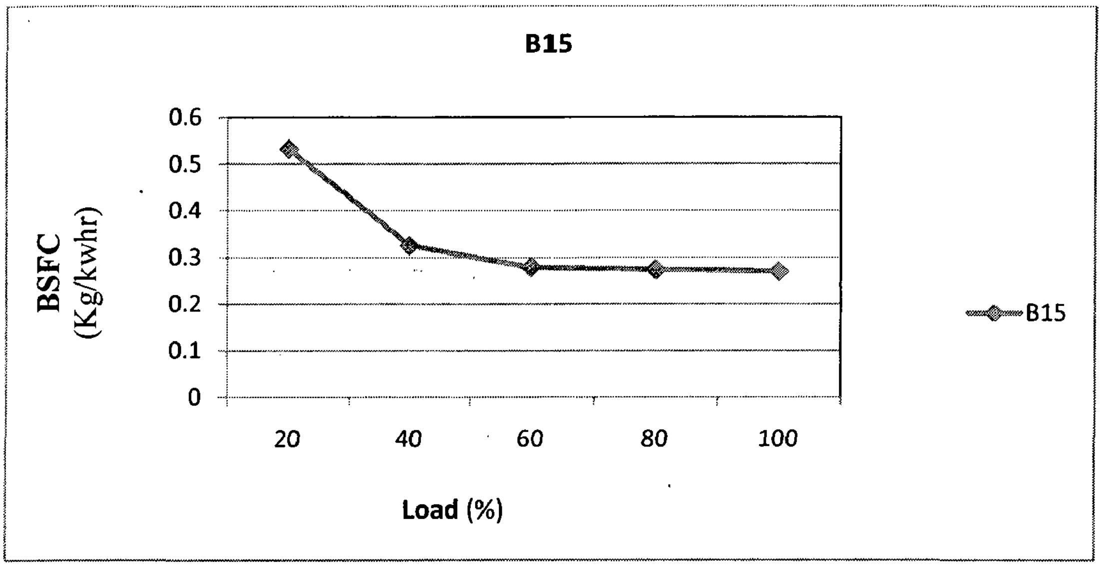


Figure 5.5 Variation of brake specific fuel consumption against the load for diesel

In case of B15, BSFC was decreased from 0.5327 to 0.2704 for with respect to increase in load from no load to 2kw. The reason for this reduction could be due to higher percentage of increase in brake power with load as compared to fuel consumption. But its BSFC was observed high at 60% loading as compared to the B10 blend due to increase percentage of karanja oil.

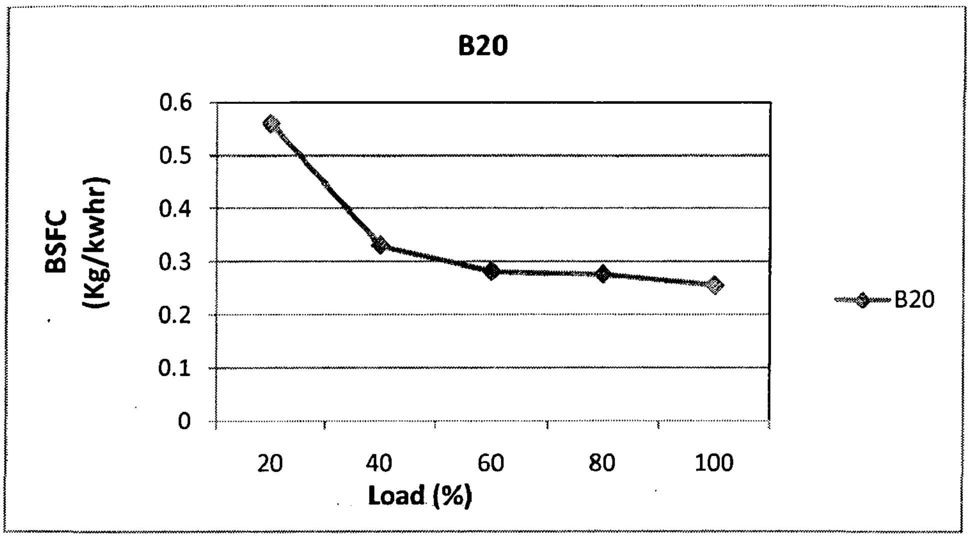


Figure 5.6 Variation of brake specific fuel consumption against the load for diesel

In case of B20, BSFC was decreased from 0.5606 to 0.2557 with respect to increase in load from no load to 2kw. The BSFC was observed slightly higher as compared to lower blends i.e. for B5, B10 and B20. The is due to higher percentage of karanja oil in diesel fuel.

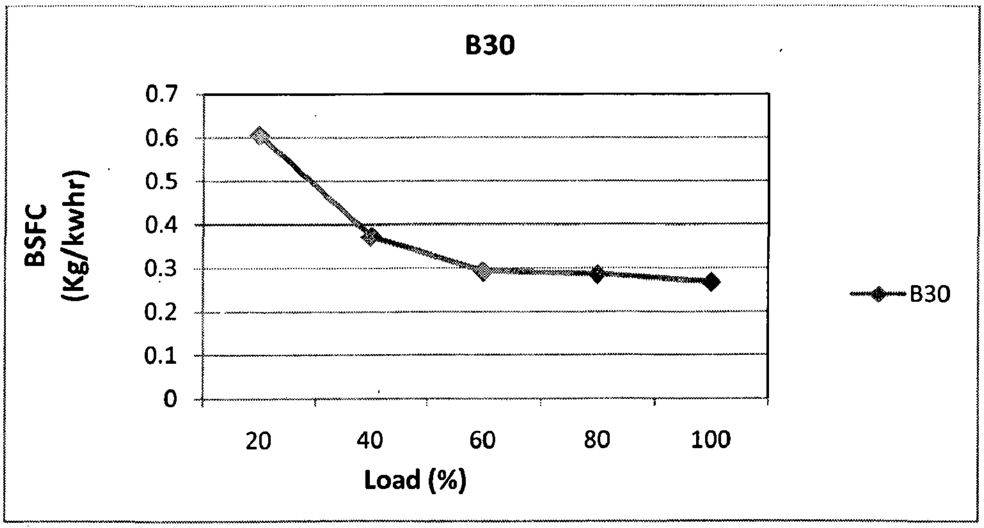


Figure 5.7 Variation of brake specific fuel consumption against the load for diesel

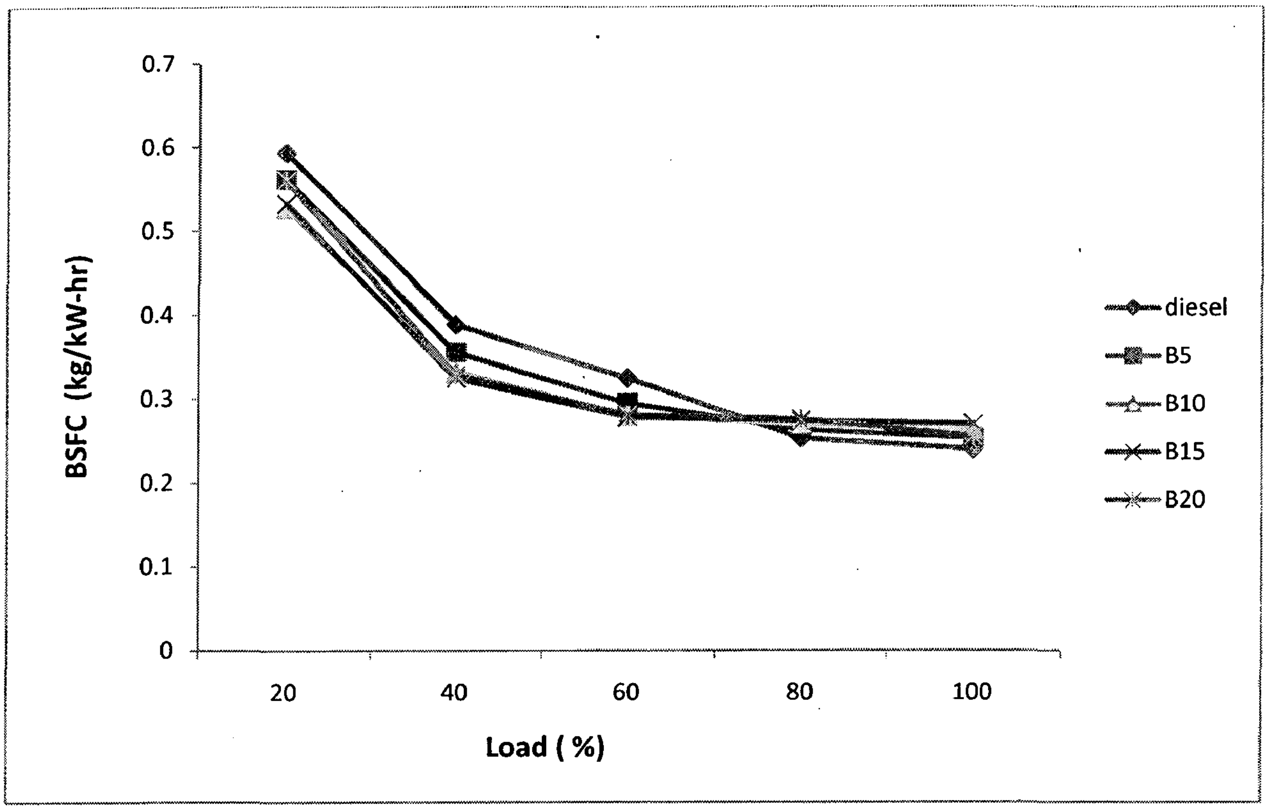


Figure 5.8 Variation of brake specific fuel consumption against the load for diesel

The BSFC reduces with increasing load the BSFC for lower blends slightly less than diesel sample upto 80% loading of the engine Another reason for the change in BSFC in blends of karanja oil in comparison to diesel may be due to a change in the combustion timing caused by the blends higher cetane number as well as injection timing.

It is observed from the graphs that BSFC reduces with increase in the load for all the blends and diesel fuel. The reverse trend in BSFC is due to increase in karanja oil percentage in diesel fuel ensuring lower calorific value.

5.1.3 Effect of blends of karanja oil and diesel on exhaust emissions of engine

Exhaust emissions due to combustion of fuels are becoming increasingly important in view of the present day awareness of the environmental pollution. If the combustion was completed, the exhaust would consist only of carbon dioxide and water vapors plus air that did not enter into the combustion process. However, for several reasons oxidation of fuel during combustion remains incomplete and produces carbon monoxide, a deadly poisonous gas, unburnt hydrocarbons and oxides of nitrogen other than particulate matter in the form of smoke.

The emission studies were carried out during engine operation by varying compression ratio and load using diesel, B5, B10, B15 B20, and B30 respectively. Constituents of exhaust emission such as carbon monoxide, carbon dioxide, sulfur dioxide and nitrogen oxides were recorded with the help of exhaust gas analyzer as discussed below:

5.1.4 Effect of load on exhaust gaseous temperature

The temperature of exhaust gases coming out of the engine gives an indication of the thermal efficiency of the engine. Heat loss is important for engine as it leads to lower working temperature and ultimately to reduced efficiency. The combustion is supposed to be completed at the end of the constant pressure burning, however in actual practice it continues up to about half of the expansion stroke. In general about 30 per cent of the energy supplied to diesel engine is lost as exhaust heat. The exhaust gas temperature depends upon the fuel-air ratio and combustion characteristics of the fuel, which in turn may depend upon the type of fuel and loading conditions as well as engine compression ratio and injection timing.

Exhaust temperature was measured during varying ratio and load and data are presented in this chapter. Exhaust gas temperatures were increased with increase in load and blend proportions.

For blend B5, B10, B15, B20 at maximum load, the exhaust gas temperature was 350°C while for diesel, B20, B40, B60 and B80 it was 323, 329, 336, 341 and 48°C, respectively.

The variation of NOX at different engine load is presented in figure The reason for the increase in NOX is not clear. The cetane numbers of the blends of karanja oil are generally higher than that of diesel fuel associated with lower NOX emission. The injection timing advancement associated with these effects could be partially responsible for the increase in NOX emissions.

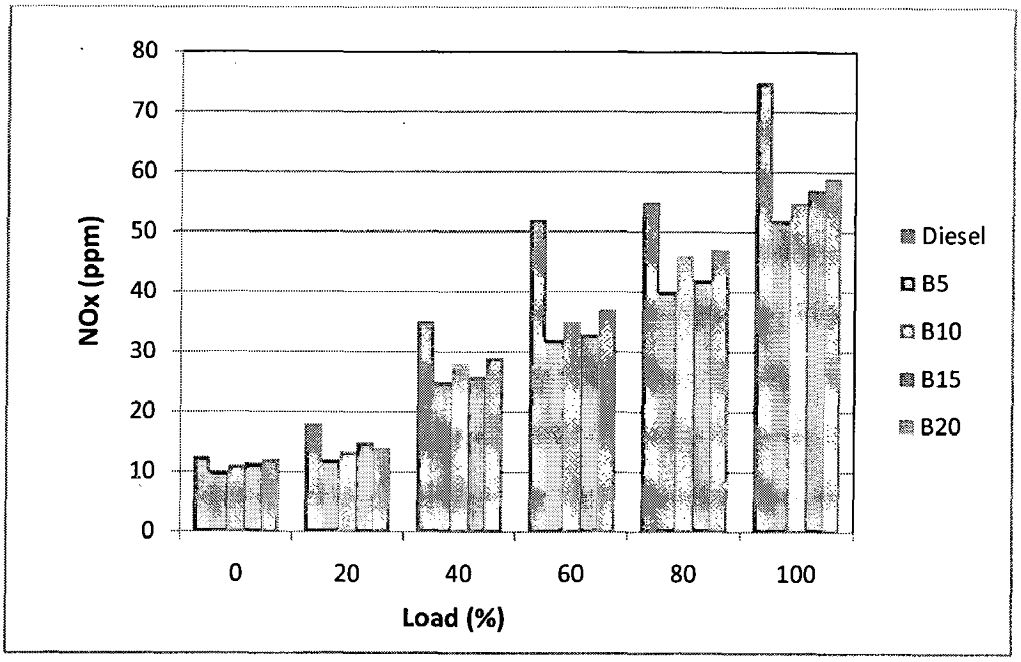


Figure 5.9 The variation of NOX at different engine load

5.2 CARBON MONOXIDE EMISSION

Carbon monoxide is a product of the incomplete combustion due to either inadequate oxygen or insufficient time for completion of the reaction. Generally, the CO values are found to vary between 0-2 per cent in case of diesel engines. It is also said that complete elimination of CO is not possible and 0.5 per cent CO should be considered as a reasonable goal. By varying load and compression ratio, the variation in CO emission was presented in Table 4.6.

For biodiesel, percentage of CO was increased with increasing load for all compression ratio. At compression ratio 14:1, 16:1, 18: and 20:1, CO emission for no load were 0.045, 0.046, 0.046 and 0.042, similarly, at high load it was 0.286, 0.287, 0.288 and 280, respectively. Initially, at no load condition, cylinder temperatures might be too low, which increased with loading due to more fuel injected inside the cylinder. At elevated temperature, performance of the engine improved with relatively better burning of the fuel resulting in lower CO at lower load. However, on further loading, the excess fuel required led to formation of more smoke, which might have prevented oxidation of CO into CO_2, consequently increasing the CO emissions sharply. For biodiesel, compression ratio 20:1 gives lower CO emission compared to other compression ratio. This may be due to lesser fuel consumption.

The minimum and maximum CO produced was 0.288 and 0.318 per cent at full load for B100 and diesel, respectively. Similar findings were also reported for Soyabean biodiesel by Schumacher *et al.*, (1996). For diesel, CO emission was higher (2.02 g kWh^{-1}) than B100 (1.43 g kWh^{-1}). Raheman and Phadatare (2004) found out the same result for Karanja biodiesel. They observed that the minimum and maximum CO produced using B20 to B100 were 0.004 and 0.016 per cent which was lesser than diesel (0.028 %).

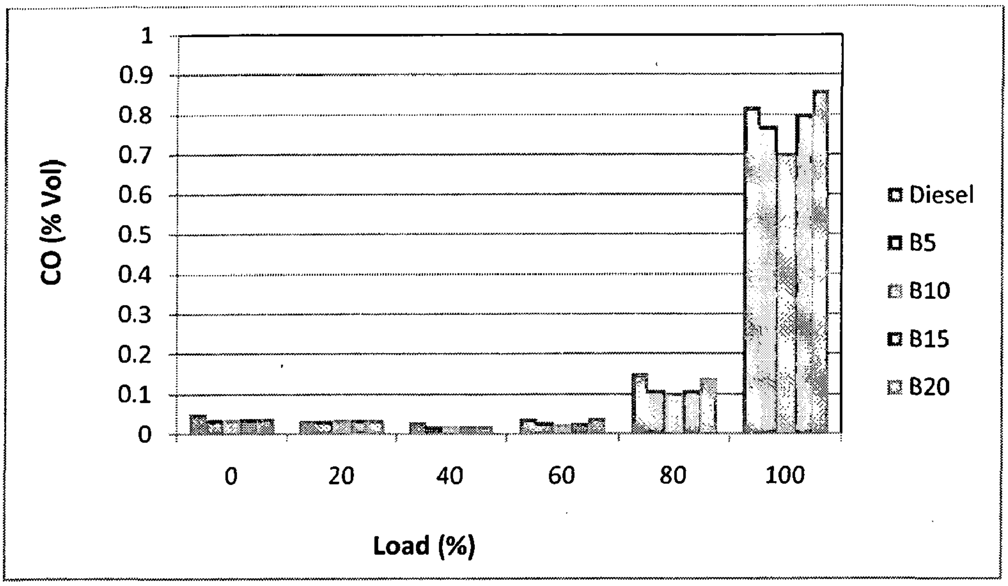


Figure 5.10 The variation of CO at different engine load

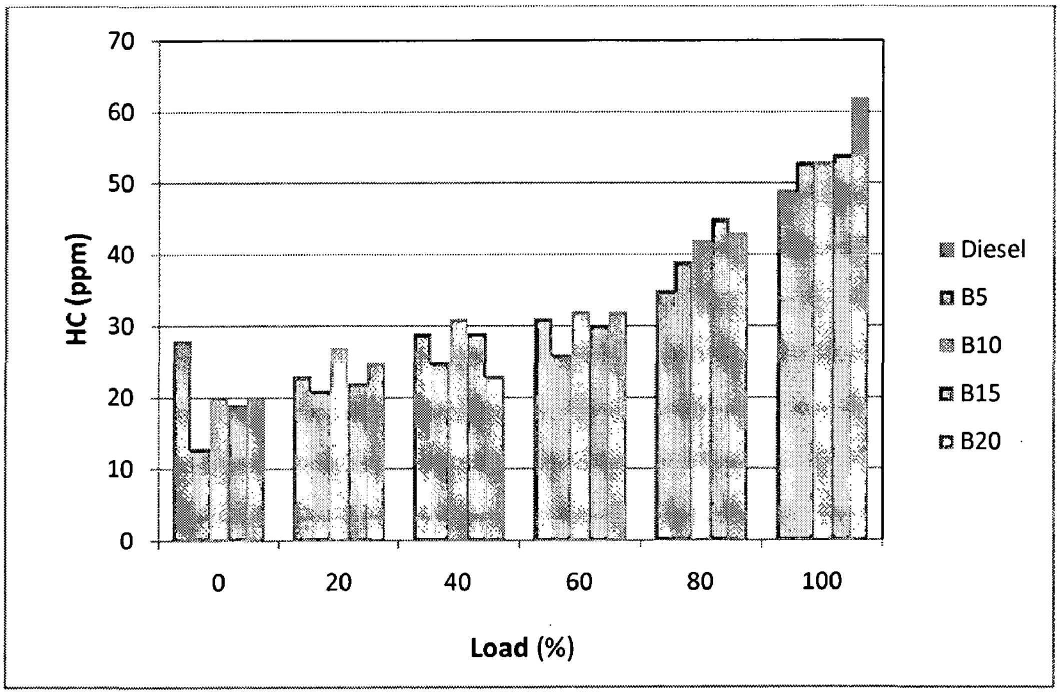


Figure 5.11 The variation of HC at different engine load

CHAPTER-6

CONCLUSIONS AND RECOMMADATIONS

6.1 CONCLUSIONS

In the present study, the performance evaluation of biodiesel engine of 2.5 kW under different loading conditions for various blends of, B5, B10, B15, B20 and B30. The exhaust gasses emitted from engine under different loading conditions were also measured, and following conclusions are drawn:

I. It was found that, the Brake Thermal Efficiency of B10 sample at 60% load is maximum among other blends, and it is also equivalent to diesel.

II. The brake specific fuel consumption for all blends is slightly less than diesel fuel, so it is possible to operate diesel engine for lower blends of B15 at 60% and 75% loading of engine.

III. The concentration of exhaust gasses emitted from engine working with all types of blends are slightly less than diesel fuel for a range of no load to full load condition of engine.

6.2 RECOMMADATION

From the above conclusions following can be recommended:

i. Karanja vegetable oil can be used as a blend with diesel up to 10% blending, & 60 to 70% loading conditions for higher part load efficiency of engine.

ii. Further experimental works can be taken up to minimize the gaseous emissions by finding the optimum blending and loading conditions of engine.

iii. An economic analysis can be carried out for the different blends of Karanja oil with diesel, working with diesel engine.

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