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Experimental Investigation of Direct Injection Compression Ignition Engine Fueled With Blends of Karanja Methyl Esters and Diesel

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ABSTRACT

This paper deals with the study of the potential substitution of Karanja methyl ester blends for diesel as fuel for automobiles and other industrial purposes. The objective of this study is the analysis of the performance, combustion and emission characteristics of the karanja methyl esters and comparing with petroleum diesel. The tests were carried out on a 4.4 KW, single cylinder, direct injection, Air-cooled diesel engine. The results of investigations carried out in studying the fuel properties of karanja methyl ester (KME) and its blend with diesel fuel from 20 to 100% by volume and in running a diesel engine with these fuels. Engine tests have been carried out with the aim of obtaining comparative measures of Brake power, specific fuel consumption and emissions such as CO_2, CO, HC, smoke density and NOx to evaluate and compute the behavior of the diesel engine running on above mentioned fuels. The reduction in exhaust emissions together with increase in brake power, brake thermal efficiency and reduction in specific fuel consumption make the blends of karanja esterified oil (B20) a suitable alternative fuel for diesel and could help in controlling air pollution.

Introduction

Energy is an essential and vital input for economic activity. Building a strong base of energy resources is a pre-requisite for the sustainable economic and social development of a country. Indiscriminate extraction and increased consumption of fossil fuels have led to the reduction in underground-based carbon resources. Biofuels will mitigate the vulnerability and the adverse effects of use of fossil fuels. Several developed countries have introduced policies encouraging the use of biofuels made from grains, vegetable oil or biomass to replace part of their fossil fuel use in transport in order to achieve the following goals; to prevent environmental degradation by using cleaner fuel, to reduce dependence on imported, finite fossil supplies by partially replacing them with renewable, domestic sources and to provide new demand for crops to support producer income and rural economics. The use of biodiesel for diesel engine applications is studied by various researchers. Some of the recent studies which dealt with transesterification, performance study and emission analysis are reported.

P.K. Srivastava et al 2008 Ref [1] in this paper he prepared Methyl ester of karanja oil by transesterification method. Physical and chemical properties of the karanja oil and that of the methyl ester are quite close to those of the diesel oil. Maximum thermal efficiency of methyl ester has been determined and found to be slightly less than that of the diesel. The brake specific fuel consumption of biodiesel of karanja oil is slightly higher as compared to diesel. The exhaust gas temperature of methyl ester is higher as compared to diesel and blends. HC, CO and NO emission are higher of methyl ester of karanja oil as compared to diesel. It appears that methyl ester of karanja oil is a suitable substitute of petroleum diesel fuel.

Y.C. Sharma et al 2008 Ref [2] In this paper he studied about the development of biodiesel from karanja tree, mainly found in rural India has been investigated. The biodiesel was developed from oil expelled from the seeds of the tree. Molecular weight of the oil was determined and found to be 892.7. Both the acid as well as alkaline esterification were subsequently performed to get the final product. NaOH was found to be a better catalyst than KOH in terms of yield. Maximum yield of 89.5% was achieved at 8:1 molar ratio for acid esterification and 9:1 molar ratio for alkaline esterification, 0.5 wt.% catalyst (NaOH/KOH) using mechanical stirrer.

Sudipta Choudhury et al 2007 Ref [3] In this paper he presents the suitability of Pongamia Pinnata (karanja) as a source of renewable fuel substituting petrodiesel in CI engine. physical and chemical properties of karanja oil suggest that it can not be used directly as CI engine fuel due to higher viscosity, density which will result in low volatility and poor atomization of oil during oil injection in combustion chamber causing incomplete combustion and carbon deposits in combustion chamber. Based on engine emission studies i.e. CO, NOX and hydrocarbon, we can say that all the parameters are within maximum limits that conclude safer use as an alternate fuel.The straight karanja oil blend upto 25% with the petrodiesel meets the standard specification. However blending of this oil with petrodiesel upto 20% (by volume) can be used safely in a conventional CI engine without any engine modification that could help in controlling air pollution.

Rajesh Kumar Pandey et al 2010 Ref [4] Biodiesel is an oxygenated fuel containing 10% to 15% oxygen by weight. Using biodiesel can help to reduce the world's dependence on fossil fuels and has significant environmental benefits. The reasons for these environmental benefits using biodiesel instead

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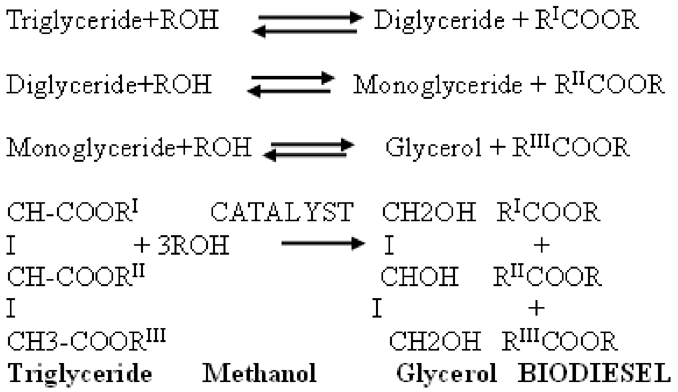
of the conventional diesel fuel reduces exhaust emissions such as the overall life circle of carbon dioxide (CO2), particulate matter (PM), carbon monoxide (CO), sulfur oxides (SOx), volatile organic compounds (VOCs), and unburned hydrocarbons (HC) significantly. Furthermore, since biodiesel can be said a sulfur-free fuel, it has 99% less SOx emission than the diesel fuel. However, most of the biodiesel produce 10% to 15% higher oxides of nitrogen (NOx) when fueling with 100% biodiesel for a cleaner air and cleaner environment. Aside from being renewable and biodegradable, biodiesel reduces most emissions while engine performance and fuel economy are nearly the same as the conventional fuel. Biodiesel, therefore, is a very promising alternative fuel that can lead to a cleaner environment.

Fatty acids composition of Karanja oil

Transesterification

Transesterification (alcoholysis) is the chemical reaction between triglycerides and alcohol in the presence of catalyst to produce mono-esters. The long and branched chain triglyceride molecules are transformed to mono-esters and glycerin. Transesterification process consists of a sequence of three consecutive reversible reactions. That is, conversion of triglycerides to diglycerides, followed by the conversion of diglycerides to monoglycerides. The glycerides are converted into glycerol and yielding one ester molecule in each step. The properties of these esters are comparable to that of diesel. The overall transesterification reaction can be represented by the following reaction scheme.



Where R^{I}, RII, & R^{III} are long chain hydrocarbons

Stoichiometrically, three moles of alcohol are required for each mole of triglyceride, but in practice a higher molar ratio is employed in order to displace the equilibrium for getting greater ester production. Though esters are the desired products of the transesterification reactions, glycerin recovery also is important due to its numerous applications in different industrial processes. Commonly used short chain alcohols are methanol, ethanol, propanol and butanol. The yield of esterification is independent of the type of alcohol used. Therefore, the eventual selection of one of these three alcohols will be based on cost and performance considerations. The methanol is used commercially because of its low price. Alkaline hydroxides are the most effective transesterification catalysts as compared to acid catalysts. Potassium hydroxide and sodium hydroxide are the commonly used alkaline catalysts. Alkaline catalyzed transesterification of vegetable oils is possible only if the acid value of oil is less than 4. Higher percentage of FFA in the oil reduces the yield of the esterification process.

Experimental Procedure

Description

Electrical swinging field dynamometer is used for measuring the brake power of the engine. This dynamometer is coupled to the engine by flexible coupling. This electrical dynamometer consists of a 5 KVA AC alternator (220V, 1500rpm) mounted on the bearings and on the rigid frame for the swinging field type loading. The output power is directly obtained by measuring the reaction torque. Reaction force (torque) is measured by using a strain gauge type load cell. A water rheostat is used to dissipate the power generated. A panel board consisting of ammeter, voltmeter switches and fuse, load cell indicator

Procedure

Before starting the experiments, all the equipments were calibrated according to the manufacturers' guidelines. The engine was started by hand cranking and was allowed to warm up at no load condition. The engine was fueled with methyl ester, traditional diesel and blends containing 20 percent, 40 percent, 60 percent and 80 percent of methyl ester. For every fuel change, the fuel lines were cleaned, and the engine was left to operate undisturbed for at least 30 minutes to stabilize on the new conditions. The following measurements were made at various loads (0%, 25%, 50%, 75% and 100% of rated load).

- Fuel consumption
- Air flow rate
- Engine output
- In cylinder pressure data

Engine emissions, digital rpm readout etc, is also provided.

Results and discussions

Performance Analysis

Specific Fuel Consumption

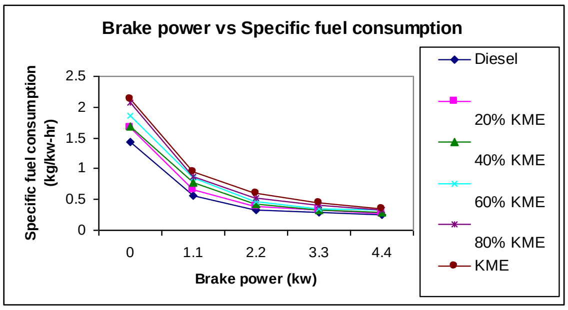


Figure. 1: Comparison of Specific Fuel Consumption for KME/diesel blends

From the figure.1, it is observed that the methyl esters shows higher SFC compare to diesel as calorific value is less. It was observed that 20% blend is having comparable closer values with diesel. However SFC is higher for all the other blends. The SFC decreases with the increasing loads. It is inversly praportional to the thermal efficiency of the engine.

Brake Thermal Efficiency

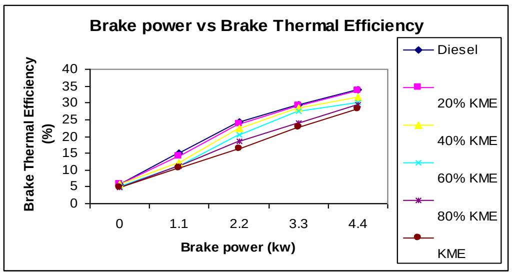


Figure.2: Comparison of brake thermal efficiency for KME/diesel blends

From the fig.2, it is observed that the BTE is slightly lower than the diesel for karanja methyl ester and its blends. The BTE is less for karanja methyl ester because of less calorific value.

From the fig.2, it is observed that brake thermal efficiency is low at low values of BP and is increasing with increase of BP for all blends of fuel. For a blend of 20% the brake thermal efficiency is high at low BP values when compared with other blends of fuel and is very close to diesel at high values of BP.ence at the blend of 20% of methyl ester the performance of the engine is good .

Emission Analysis

CO_2 Emission

From figure. 3, it is observed that CO_2 increases with increasing load for all the blends of Karanja methyl esters. If percentage of blends of Karanja methyl esters increases, CO_2 increases. The CO_2 emissions are directly proportional to the percentage of Karanja in the fuel blend. Since Karanja methyl esters is an oxygenated fuel, it improves the combustion efficiency and hence increases the concentration of CO_2 in the exhaust.

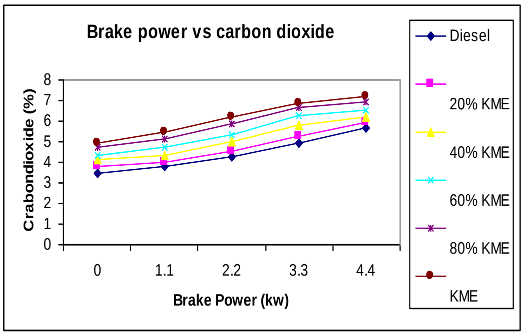


Figure .3: Comparison of CO_2 for KME/diesel blends

CO Emission

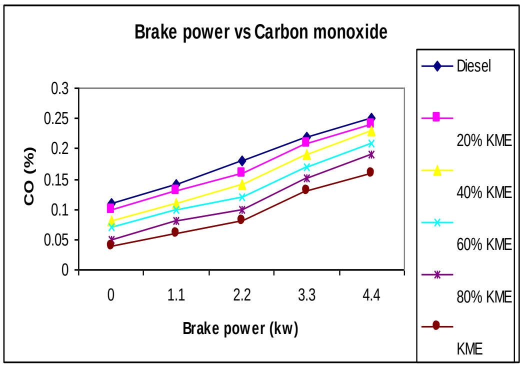


Figure.4: Comparison of CO for KME/diesel blends

From figure.4, it is observed that CO decreases with increasing load for all the blends of Karanja methyl esters. If percentage of blends of Karanja methyl esters increases, CO reduces. The concentration of CO decreases with the increase in percentage of KME in the fuel. This may be attributed to the presence of O_2 in KME, which provides sufficient oxygen for the conversion of carbon monoxide (CO) to carbon dioxide (CO_2). It can be observed that blending 20% KME with diesel results in a slight reduction in CO emissions when compared to that of diesel.

HC Emission (in PPM)

From figure.5 it is observed that hydro carbon (HC) increases with increasing load for all the blends of Karanja methyl esters. If percentage of blends of Karanja methyl esters increases, HC reduces. The hydrocarbon emissions are inversely proportional to the percentage of KME in the fuel blend. A significant difference between KME and diesel operation can be inferred. The diesel oil operation showed the highest concentrations of HC in the exhaust at all loads. Since KME is an oxygenated fuel, it improves the combustion efficiency and hence reduces the concentration of hydrocarbon emissions (HC) in the engine exhaust. Blending 20% KME with diesel greatly reduces HC emissions especially at rated load condition.

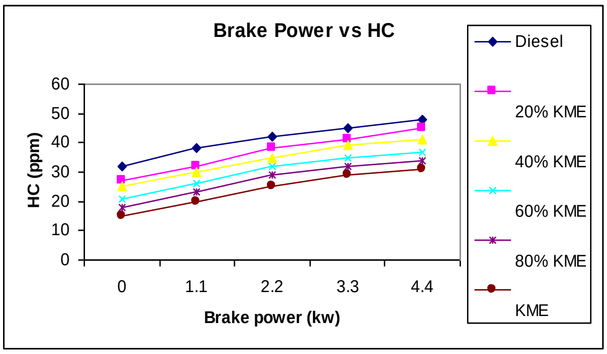


Figure .5: Comparison of HC for KME/diesel blends

NOx Emission

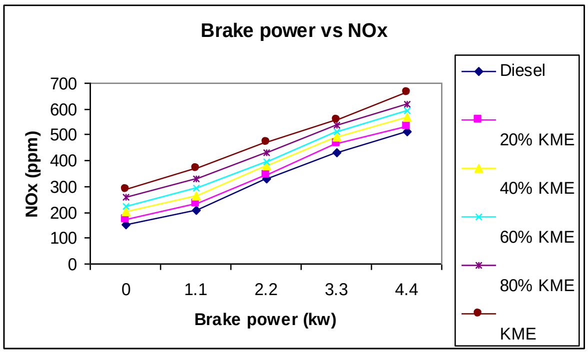


Figure. 6: Comparison of nitrogen oxides for KME/diesel blends

From figure.6, it is observed that NOx increases with increasing load for all the blends of karanja methyl esters. If percentage of blends of karanja methyl esters increases, NOx increases. It can be seen that NOx emissions increase with increase in percentage of KME in the diesel-KME fuel blend. The NOx increase for KME may be associated with the oxygen content of the KME, since the fuel oxygen may augment in supplying additional oxygen for NOx formation. Moreover, the higher value of peak cylinder temperature for KME when compared to diesel may be another reason that might explain the increase in NO_X formation.

Smoke density

From figure.7, it is observed that smoke density increases with increasing load for all the blends of Karanja methyl esters. If percentage of blends of Karanja methyl esters increases, smoke density decreases. Because of increasing the load the fuel entering in to the cylinder increases in that proper oxygen is not allowed for that the smoke density is high for the diesel.

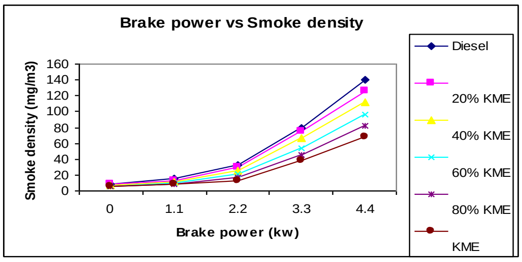


Figure. 7: Comparison of Smoke density for KME/diesel blends

Combustion Analysis

Figures 8 –12 show the variation of cylinder pressure with crank angle at rated power (4.4kW) for diesel, blends of 20%, 40%, 60% and 80% and 100% of KME. All the blend fuels show the same trend except for slight changes in values of pressure at various crank angles. There are three distinct regions: Region I (From the start of combustion to 4^0 bTDC): The cylinder pressure is higher for methyl ester and its blends compared to diesel. In this region, the cylinder pressure increases with the increase in percentage of methyl ester in the blend. This is due to the lower ignition delay of methyl ester and its blends. The combustion starts earlier and the motion of the piston towards TDC also helps the rise in gas pressure.

Region II (4^0 bTDC to 10^0 aTDC): In this region the cylinder pressure is lower for all the blends of methyl esters compared to diesel. This is mainly because of the lower heat release of methyl esters and its blends due to their lower calorific values. Since the specific heat capacity of exhaust gas of methyl ester operated engines is high compared to diesel, it absorbs more heat energy thereby reducing the high temperature and pressure of the gas in the cylinder.

Region III (after 10^0 aTDC): The methyl ester and its blends show slightly higher pressure in cylinder due to the late combustion of higher fatty acid components in methyl ester.

It is also observed that the crank angle at which peak pressure occurs shifts away from TDC slightly. For example, the peak pressure at rated power (4.4kW) occurs at 8^0CA aTDC for diesel, 20B KME, 40B KME, 60B KME, 80B KME and 7^0CA aTDC KME.

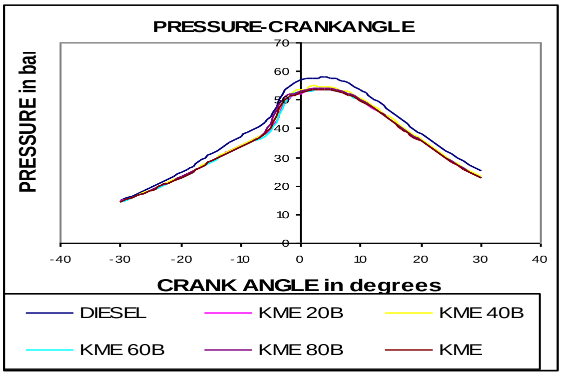


Figure.8: Pressure – crank angle diagram for KME /diesel blends at no load

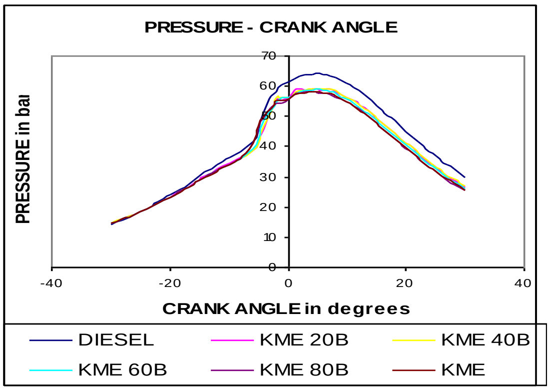


Figure.9: Pressure – crank angle diagram for KME /diesel blends at ¼ load

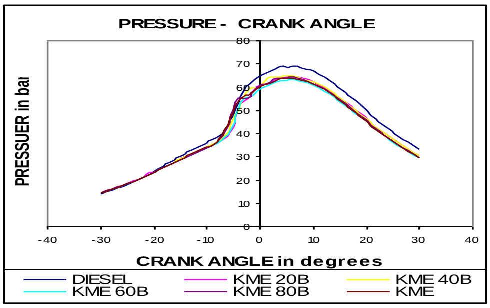


Figure.10: Pressure – crank angle diagram for KME /diesel blends at ½ load

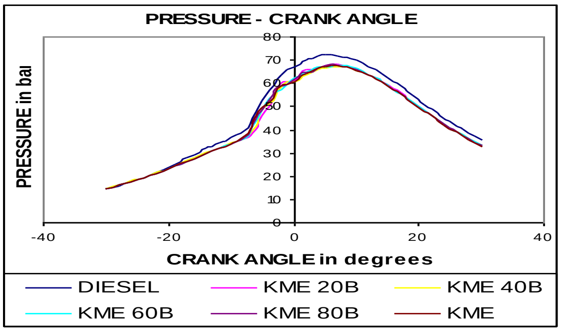


Figure.11: Pressure – crank angle diagram for KME /diesel blends at ¾ load

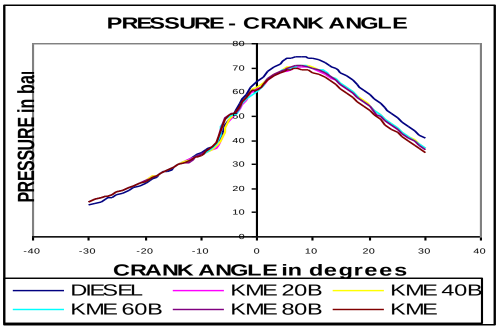


Figure.12: Pressure – crank angle diagram for KME /diesel blends at full load

Conclusion

The Performance, Combustion and Emissions characteristics of a 4.4 kW direct injection compression ignition engine fuelled with KME and its blends have been analyzed, and compared to the baseline diesel fuel. The results of present work are summarized as follows:

- The specific fuel consumption increases with increase in percentage of KME in the blend due to the lower calorific value of KME.
- The brake thermal efficiency decreases with increase in percentage of KME in the fuel.
- Increase in oxygen content in the KME-diesel blends as compared to diesel results in better combustion and increase in the combustion chamber temperature. This leads to increase in NO_X. KME recorded higher values of NO_X compared to diesel at rated load.
- Emissions of CO and HC decrease with increase in percentage of KME in the blend.
- It is also observed that smoke density increases with increasing load for all the blends of Karanja methyl esters. If percentage of blends of Karanja methyl esters increases, smoke density decreases.
- It is observed that the crank angle at which peak pressure occurs shifts away from TDC slightly. The peak pressure at

rated power (4.4kW) occurs at 8^0CA aTDC for diesel (74.629 bar), 20B KME (70.215 bar), 40B KME (70.847 bar), 60B KME (70.861 bar), 80B KME (70.991 bar), and KME 7^0CA aTDC (69.554 bar).

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Table :1 Composition of Karanja oil

Sl.No.	Fatty acids	Composition (%)
1	Palmitic (C16:0)	11.6
2	Stearic (C18:0)	7.5
3	Oleic (C18:1)	51.5
4	Linoleic (C18:2)	16.0
5	Linolenic(C18:3)	2.6
6	Arachidic (C20:0)	1.7
7	Eicosenoic (C20:1)	1.1
8	Behenic(C22:0)	4.3
9	Lignoceric (C24:0)	1.0

Table .2: Specifications of CI Engine

Engine Type	Four stroke, stationary, constant speed, direct injection, diesel engine
Make	Kirloskar
Model	TAF1
Maximum Power	4.4 kW @ 1500 RPM
Maximum Torque	28 N-m @ 1500 RPM
Bore	87.5 mm
Stroke	110 mm
Compression Ratio	17.5:1
Injection Timing	23.4^0 bTDC
Loading Type	Electrical Dynamometer