THE EFFECT OF KARANJA OIL METHYL ESTER ON KIRLOSKAR HA394DI DIESEL ENGINE PERFORMANCE AND EXHAUST EMISSIONS

by

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Biofuels are being investigated as potential substitutes for current high pollutant fuels obtained from the conventional sources. The primary problem associated with using straight vegetable oil as fuel in a compression ignition engine is caused by viscosity. The process of transesterifiction of vegetable oil with methyl alcohol provides a significant reduction in viscosity, thereby enhancing the physical properties of vegetable oil. The Kirloskar HA394 compression ignition, multi cylinder diesel engine does not require any modification to replace diesel by karanja methyl ester. Biodiesel can be used in its pure form or can be blended with diesel to form different blends. The purpose of this research was to evaluate the potential of karanja oil methyl ester and its blend with diesel from 20% to 80% by volume. Engine performance and exhaust emissions were investigated and compared with the ordinary diesel fuel in a diesel engine. The experimental results show that the engine power of the mixture is closed to the values obtained from diesel fuel and the amounts of exhaust emissions are lower than those of diesel fuel. Hence, it is seen that the blend of karanja ester and diesel fuel can be used as an alternative successfully in a diesel engine without any modification and in terms of emission parameters; it is an environmental friendly fuel

Key words: *Kirloskar engine, karanja biodiesel, performance, exhaust emissions, heavy-duty engine*

Introduction

Karanja (*Pongamia pinnata*) is a native of the Western Ghats and chiefly found along the banks of streams and rivers or near the sea on beaches and tidal forests. It also grows in dry places far in the interior and up to an elevation of 1000 m. It grows all over the country, from the coastline to the hill slopes. It needs very little care and cattle do not browse it. It has rich leathery

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evergreen foliage that can be used as green manure. From year-5, the plant is expected to give economic yields and it may continue throughout its life of 100 years. When it blooms, the pongamia trees are used for bee harvesting and honey production. It has been learned from the representatives of the State Governments in India, that there is ample scope for cultivation of non-edible oil seeds plants in most States [1, 2]. The plants, which can normally be cultivated for this purpose, are Neem, Mahua, Karanja, Kusum, Palm, Linseed, Jatropha, *etc*. It is for this reason that the Planning Commission has started a National Mission on jatropha curcas, which includes large-scale plantation, collection of seeds and setting up of plants for producing biodiesel [3].

Raheman *et al.* [4] reported that, the brake-specific fuel consumption for B20 and B40 diesel oil were 0.1-1.3% higher than that of diesel when tested with karanja biodiesel blend as fuel. Srinivas Rao *et al*. [5] investigated the use of non-edible vegetable oils as alternative fuels in diesel engine. They have reported the results of tests conducted on an AVI type Kirloskar DI diesel engine with karanja oil, ricebran oil, neem oil, jatropha oil, and the corresponding methyl esters of these oils. They presented that brake thermal efficiency has been found to be lower for vegetable oils. Bhanodaya Reddy *et al.* [6] studied the use of non-edible oil (pongamia oil) as an alternative to diesel fuel. They adopted blends of 10, 20, 30, 40, and 50% pongamia oil and diesel oil. They observed smooth running of the engine at 50% blend of Pongamia oil and also observed that the 20% blend of pongamia oil with 80% diesel gave the better performance with lower emissions compared to all blends. Singh *et al*., [7] reported a technique to produce biodiesel from karanja oil. Basavaraj *et al*. [8] found in their investigations that, brake thermal efficiency of engine with honge methyl ester as fuel is marginally lower than diesel as fuel and BSFC is lower for B20 comparing with other blends.

The main purposes of this study was to investigate the methyl ester of karanja oil and diesel fuel mixture as a fuel in a Kirloskar HA394 DI diesel engine and to determine engine performance and exhaust emission characteristics. In the study, methyl ester of karanja oil is blended with diesel fuel at 20%, 40%, 60%, and 80% ratio on volume basis in order to reduce the high viscosity of methyl ester of karanja oil. The experimental results are compared with those of ordinary diesel fuel.

Experimental

Fuel properties

The test fuel sample of karanja biodiesel was obtained directly from Tinna Oils & Chemicals Ltd., Latur, India, manufacturers and suppliers of karanja and fish oil biodiesel to TATA Motors. The physical characteristics of karanja methyl ester are closer to diesel oil. The fuel properties of karanja methyl ester (KOME) and diesel fuel were tested in Bangalore Test House, Bangalore, India and listed in tab. 1.

Table 1. Fuel properties of diesel oil and methyl ester of karanja oil

Properties	Diesel	Karanja oil biodiesel
Density [kgm^{-3}]	850	885
Specific gravity	0.85	0.885
Kinematic viscosity at 40 °C [Cst]	3.05	5.0
Higher calorific value [$kJkg^{-1}$]	42800	41445
Flash point [°C]	56	171
Fire point [°C]	63	184

Experimental setup

Tests was conducted on a Kirloskar Engine HA394, four strokes, three cylinders, air-cooled direct injection, and naturally aspirated diesel engine with displacement of 2826 cm^3, bore 100 mm, stroke 120 mm, compression ratio of 17:1 and runs at constant speed of 1500 rpm. The engine was coupled to a generator set and loaded by electrical resistance to apply different engine loads. The voltage, current and power developed by engine were directly displayed on control panel. The layout of experimental test rig and its instrumentation is shown in fig. 1 (tab. 2).

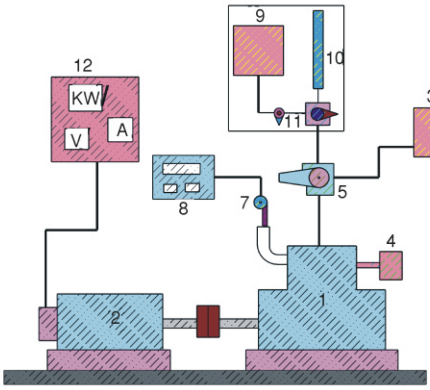

Figure 1. Lay-out of experimental setup with instrumentation
1 – Kirloskar HA394, 2 – Alternator, 3 – Diesel tank, 4 – Air filtera, 5 – Three way valve, 6 – Exhaust pipe, 7 – Probe, 8 – Exhaust gas Analyzer, 9 – Biodiesel tank, 10 – Burette, 11 – Three way valve, 12 – Control panel

Table 2. Engine specification

Make	Kirloskar engine
Model	HA394
Number cylinders	3 in line
Aspiration	Natural
Bore and stroke	100 mm 120 mm
BHP/BP	32.5/20 kW
Rated power	25 kVA
Displacement	2826 cm^3
Type of cooling	Air-cooled
Fuel consumption at 90% load	5 liters per hour
Firing order	1-3-2
Speed	1500 rpm
Compression ratio	17: 1

Experimental procedure

The series of exhaustive engine tests were carried out on Kirloskar HA394 diesel engine using diesel and karanja biodiesel blends as well as separately on fuels at 1500 rpm. Performance and emission tests were conducted on various biodiesel blends in order to optimize the blends concentration for long-term usage in CI engines. To achieve this, several blends of varying concentration were prepared ranging from 0% (neat diesel oil – B0) to 80% through 10% (B10), 20% (B20), 40% (B40), 60% (B60), and 80% (B80) by volume. The performance data was then analyzed from the graphs recording power output, fuel consumption, specific fuel consumption, thermal efficiency for all blends of biodiesel. The major pollutants appearing in the exhaust of a diesel engine are carbon monoxide, hydrocarbon, and oxides of nitrogen. For measuring exhaust emissions, QRO-402 analyzer was used. The brake specific fuel consumption is not a very reliable parameter to compare the two fuels as the calorific value and the density of the blend follow slightly different trend. Hence, brake specific energy consumption is a more reliable parameter for comparison. For an optimum biodiesel system, the blend concentration has been determined based on maximum thermal efficiency at all loads and minimum brake specific energy consumption.

Results and discussion

Fuel properties

The colour of biodiesel observed to be brown. The various fuel properties of karanja biodiesel were determined. The characteristics of biodiesel are close to mineral diesel, and therefore biodiesel becomes a strong candidate to replace the mineral diesel, if need arises. Table 1 summarizes the results of fuel tests of diesel fuel and karanja oil methyl ester.

Engine performance

The engine performance with karanja oil biodiesel was evaluated in terms of brake specific fuel consumption, brake specific energy consumption, thermal efficiency, and exhaust gas temperature at different loading conditions of the engine.

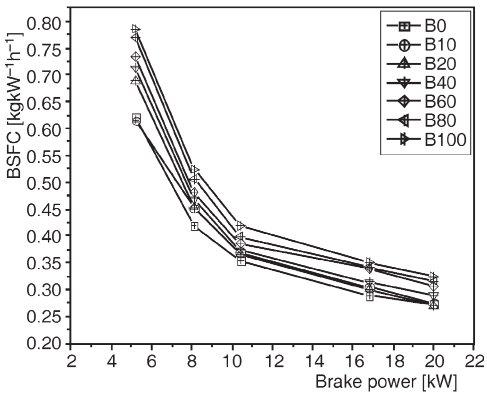

Figure 2. Comparison of BSFC with brake power for diesel, methyl ester of karanja oil and its blends

Brake-specific fuel consumption

The variation of brake-specific fuel consumption (BSFC) with load for different fuels is presented in fig. 2. For all fuel tested, BSFC decreased with increase in load. As the BSFC was calculated on weight basis, obviously higher densities resulted in higher values for BSFC. As density of karanja biodiesel was higher than that of diesel, for the same fuel consumption on volume basis, 100% biodiesel yield higher BSFC. The higher densities of biodiesel blends caused higher mass injection for the same volume at the same injection pressure. The calorific value of biodiesel is less than diesel. Due to these reasons, the BSFC for other blends were higher than that of diesel. Similar trends of decrease in the BSFC value with increasing load for different biodiesel blends were also reported by other researchers [4, 7-9] while testing biodiesel obtained from karanja, mahua and honge oils. Reverse trends has been observed by researcher [10, 11].

Brake specific energy consumption

Brake specific energy consumption (BSEC) is an ideal variable because it is independent of the fuel. Hence, it is easy to compare energy consumption rather than fuel consumption. The variation in BSEC with load for all fuels is presented in fig. 3. The BSEC is higher for methyl ester than diesel. The high specific energy consumption (SEC) is due to the lower energy content of the ester.

The BSEC for B20 found to be lower than diesel at full load where as BSEC for B40, B60, B80, and B100 are observed to be higher than that of diesel. The reverse trend observed may be due to lower calorific value of the blend with increase in percentage. Different trends of

BSEC with increasing load in different biodiesel blends were also reported by some researchers [10, 12, 13] while testing biodiesel obtained from linseed, mahua, and rice bran oils.

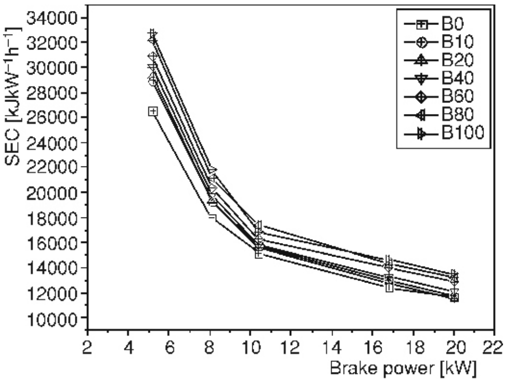

Figure 3. Comparison of BSEC with brake power for diesel, methyl ester of karanja oil, and its blends

Brake thermal efficiency

The variation of brake thermal efficiency (BTE) with load for different fuels is presented in fig. 4. In all cases, BTE increases with increase in load. This may be attributed to reduction in heat loss and increase in power with increase in load. The maximum thermal efficiency for B20 (31.28%) was higher than that of diesel. The BTE obtained for B40, B60, B80, and B100 were less than that of diesel. This lower BTE obtained could be due to reduction calorific value and increase in fuel consumption as compared to B20. The blend of 20% also gives minimum BSEC. Hence, this blend was selected as optimum blend for further investigations and long-term operation. It is observed that the thermal efficiency of diesel engines is not appreciably affected when substituting diesel by biodiesel fuel either pure or blended. Similar observations have been reported by Lapuerta *et al.* [14].

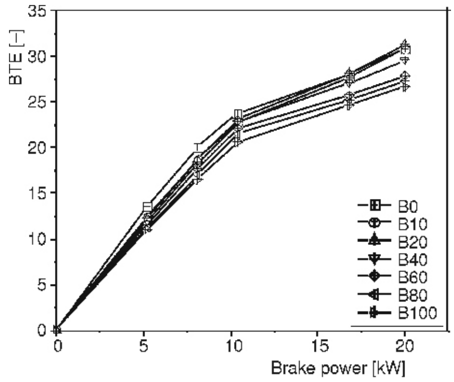

Figure 4. Comparison of thermal efficiency with brake power for diesel, methyl ester of karanja oil, and its blends

Exhaust gas temperature

The variations of exhaust gas temperature (EGT) with respect to engine loading are presented in fig. 5. In general, the EGT increased with increase in engine loading for all the fuel tested. The mean temperature increased linearly from 164 °C at no load to 402 °C at full load condition. This increase in EGT with load is obvious from the simple fact that more amount of fuel was required in the engine to generate that extra power needed to take up the additional loading. The EGT found to be increased with the increasing concentration of biodiesel in the blends, due to proper combustion as biodiesel contains 10 to 12% oxygen present in it.

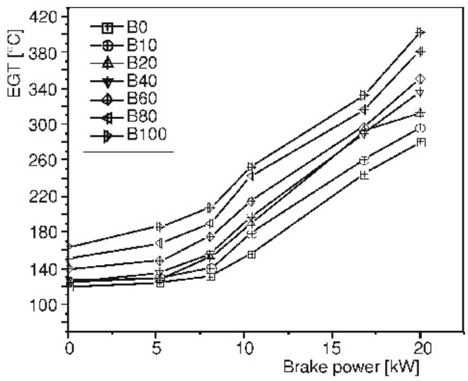

Figure 5. Comparison of exhaust gas temperature with brake power for diesel, methyl ester of karanja oil, and its blends

Engine emissions

The engine emissions with karanja biodiesel have been evaluated in terms of CO, HC, and NO_x at different loading conditions of the engine.

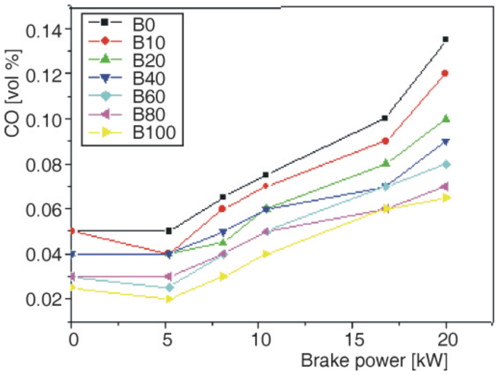

Figure 6. Comparison of CO with brake power for diesel, methyl ester of karanja oil, and its blends

Carbon monoxide

Variation of CO emissions with engine loading for different fuel is compared in fig. 6. The CO produced with the B100 is in the range of 0.015 to 0.065% which results in maximum reduction of Co by 70% as compared to diesel. It is observed that the CO emissions for biodiesel and its blends are lower than that of diesel fuel. The lower CO emissions of biodiesel blends may be due to their more complete oxidation as compared to diesel. Some of the CO produced during combustion of biodiesel might have converted into CO_2 by taking up the extra oxygen molecule present in the biodiesel chain and thus reduces CO formation. It can be observed from fig. 6 that the CO initially decreased with load and latter increased sharply up to full load. This trend was observed for all the fuel blends tested.

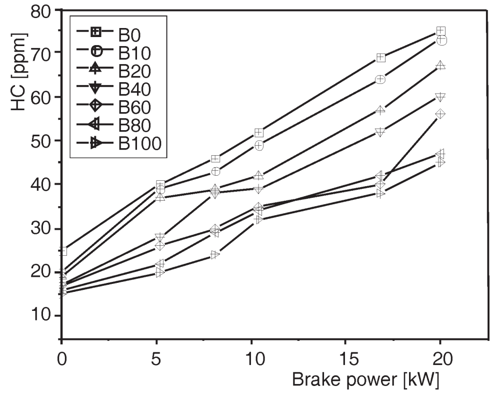

Figure 7. Comparison of HC with brake power for diesel, methyl ester of karanja oil, and its blends

Hydrocarbon

It is seen in fig. 7 that there is a significant decrease in the HC emission level with blends of methyl ester of karanja oil as compared to pure diesel operation. There is from 75 ppm to 44 ppm at the maximum power output. These reductions indicate that more complete combustion of the fuels and thus, HC level decreases significantly. The reduction in HC emission was linear with the addition of biodiesel for the blends.

Nitrogen oxides

The NO_x values for different fuel blends of diesel and B100 in exhaust emissions of Kirlosker HA394 are plotted as a function of load in fig. 8. The amount of NO_x produced for B10 to B100 is in the range of 154-500 ppm as compared to that of diesel which varies from 120-439 ppm. From fig. 8 it can be seen that the increasing proportion of biodiesel in the blends increases NO_x emissions as compared with that of pure diesel. This could be attributed to the increased exhaust gas temperatures and the fact that biodiesel had some oxygen content in it which facilitated NO_x formation. In general, the NO_x concentration varies linearly with the load of the engine. As the load increases, the overall fuel-air ratio increases resulting in an increase in the average gas temperature in the combustion chamber and hence NO_x formation, which is sensitive to temperature increase.

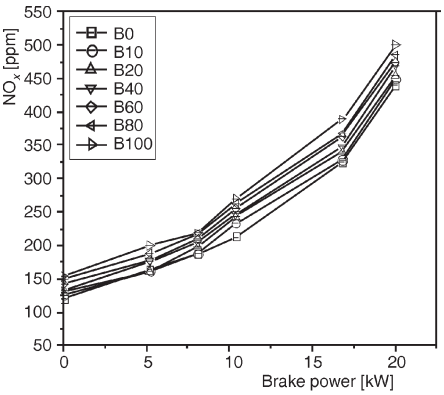

Figure 8. Comparison of NO_x with brake power for diesel, methyl ester of karanja oil and its blends

Conclusions

Based on the results of this study, the following specific conclusions were drawn.

In terms of fuel properties and exhaust emission characteristics, karanja oil methyl ester can be regarded as an alternative to diesel fuel.

Brake specific fuel consumption for B100 is higher than the diesel fuel and it is decreased in blended fuels. In B20 fuel the BSFC is lower than the diesel fuel and all other fuel.

The maximum thermal efficiency for B20 (31.28%) was higher than that of diesel at full load. The brake thermal efficiency obtained for B40, B60, B80, and B100 were less than that of diesel.

The exhaust temperature increased as a function of the concentration of biodiesel blend *i. e*. higher the percentage of karanja oil methyl ester.

Increase in the exhaust temperature of a biodiesel-fuelled engine led to approximately 13.8% increase in NO_x emissions for B100. This is due to the higher temperatures in biodiesel-fuelled engines.

The reduction in CO and HC was linear with the addition of biodiesel for the blends tested. These reductions in CO and HC indicate the complete combustion of the fuel.

Nomenclatures

BSFC – brake specific fuel consumption, [$kgkW^{-1}h^{-1}$]
BSEC – brake specific energy consumption, [$kgkW^{-1}h^{-1}$]
BTE – brake thermal efficiency, [–]
CI – compresion ignition
DI – direct injection
EGT – exhaust gas temperature, [°C]
KOME – karanja oil methyl ester
SEC – specific energy consumption, [$kgkW^{-3}h^{-1}$]

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