VOL. 5, NO. 2, FEBRUARY 2010 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences
©2006-2010 Asian Research Publishing Network (ARPN). All rights reserved.

www.arpnjournals.com

EMISSION AND PERFORMANCE CHARACTERISTICS OF KARANJA BIODIESEL AND ITS BLENDS IN A C.I. ENGINE AND IT'S ECONOMICS

Nagarhalli M. V.[1], Nandedkar V. M.[2] and Mohite K.C.[3]
[1]Department of Mechanical Engineering, SRES College of Engineering, Kopargaon, India
[2]Department of Production Engineering, Shri Guru Gobindsinghji Institute of Engineering and Technology, Nanded, India
[3]School of Energy Studies, University of Pune, Pune, India
E-Mail: nagarhalli@rediffmail.com

ABSTRACT

In the present investigation experimental work has been carried out to analyze the emission and performance characteristics of a single cylinder 3.67 kW, compression ignition engine fuelled with mineral diesel and diesel-biodiesel blends at an injection pressure of 200 bar. The performance parameters evaluated were break thermal efficiency, break specific energy consumption (BSEC) and the emissions measured were carbon monoxide (CO), carbon dioxide (CO_2), hydrocarbon (HC), and oxides of nitrogen (NO_x). The results of experimental investigation with biodiesel blends were compared with that of baseline diesel. The results indicate that the CO emissions were slightly higher, HC emissions decreased from 12.8 % for B20 and 2.85 % for B40, NO_x emissions decreased up to 39 % for B20 and 28 % for B40. The efficiency decreased slightly for blends in comparison with diesel. The BSEC was slightly more for B20 and B40. From the investigation it can be concluded that biodiesel can be used as an alternative to diesel in a compression ignition engine without any engine modifications.

Keywords: diesel engine, karanja biodiesel, engine performance, exhaust emissions, cost comparison.

INTRODUCTION

The ever increasing number of automobiles has lead to increase in demand of fossil fuels (petroleum). The increasing cost of petroleum is another concern for developing countries as it will increase their import bill. The world is also presently confronted with the twin crisis of fossil fuel depletion and environmental degradation. Fossil fuels have limited life and the ever increasing cost of these fuels has led to the search of alternative renewable fuels for ensuring energy security and environmental protection. For developing countries fuels of bio-origin can provide a feasible solution to this crisis. Certain edible oils such as cottonseed, palm, sunflower, rapeseed, safflower can be used in diesel engines. For longer life of the engines these oils cannot be used straightway. These oils are not cost effective to be used as an alternate fuel in diesel engines at present. Some of the non-edible oils such as mahua, castor, neem (*Azadiracta indica*), rice bran, linseed, Karanja (*Pongamia pinnata*), jatropha (*Jatropha curcas*) etc. can be used in diesel engines after some chemical treatment. The viscosity and volatility of these vegetable oils is higher, and these can be brought down by a process known as "transesterification". Biodiesel has a higher cetane number than petroleum diesel, no aromatics and contains upto 10% oxygen by weight. The characteristics of biodiesel reduce the emissions of carbon monoxide (CO), hydrocarbon (HC) and particulate matter (PM) in the exhaust gas as compared with petroleum diesel [1, 2].

Sanjib Kumar Karmee *et al*., [3] have prepared biodiesel of Pongamia Pinnata with a yield of 95% using methanol and potassium hydroxide as a catalyst. The viscosity of the oil decreased from 74.14 Cst (at 30°) to 4.8 Cst (at 40°C) on transesterification and the flash point was 150°C. Both these properties meet the ASTM and German biodiesel standards. Suresh Kumar *et al*., [4] have investigated the performance and emission characteristics on a single cylinder diesel engine and reported decrease in NOx and HC emissions. A 40% blend (B40) of biodiesel in diesel has been recommended by the authors.

Recep Altin *et al*., [5] have studied the potential of using vegetable oils and their methyl esters in a single cylinder diesel engine. They have used raw sunflower, cottonseed, soybean oils and their methyl esters. Their results indicate a reduction in NO_x emission and methyl esters are better than raw oils due to their inherent property of high density, higher viscosity, gumming and lower cetane number. Banapurmath *et al*., [6] have reported tests on a single cylinder C.I. engine with 3 different biodiesels viz methyl esters of honge, jatropha and sesame. All the fuels gave a slightly lower efficiency. HC and CO emissions were slightly higher and NO_x emission decreased by about 10%. They have reported that these oils can be used without any major engine modifications.

Many researches have used Methyl esters of *Pongamia pinnata* [7,8], mahua oil [9], rapeseed oil [10], linseed oil [11], soybean [12,13], jatropha [14], cottonseed [15,16,17], and palm oil [18] reported the performance and emission characteristics in diesel engines. Barnwal *et al*., [19] have discussed about prospects of biodiesel production from vegetable oils in India. They have also given the yield and production cost of various methyl esters, in general non-edible oils. The methyl esters of non-edible oil are much cheaper than petroleum diesel. The objective of this paper is to investigate the performance and emission characteristics of a single cylinder, 4 stroke, constant speed, water cooled diesel

VOL. 5, NO. 2, FEBRUARY 2010 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences
©2006-2010 Asian Research Publishing Network (ARPN). All rights reserved.
www.arpnjournals.com

engine with diesel and blends of bio-diesel and diesel (B20, B40) at a fuel injection pressure of 200 bar.

EXPERIMENTAL SET-UP

A typical 3.75 kW single cylinder, 4-stroke, constant speed (1500 rpm) diesel engine used for agricultural applications in rural India was selected for investigation to study the performance and emissions. The engine was coupled to an eddy current dynamometer (Make-BENZ SYSTEMS, PUNE, INDIA), Figure-1. The specifications of the engine are given in Table-1. Tests were conducted using diesel and biodiesel-diesel blends at no load, 33.3%, 66.6% and 100% of rated load of the engine at the rated speed of 1500 rpm. A blend of 20% biodiesel and 80% diesel (by volume) is denoted by B20. The performance parameters, efficiency and brake specific energy consumption (BSEC) are compared.

Exhaust gas composition was measured using NDIR based exhaust gas analyzer [Make: AVL Austria; Model: Digas 444]. The analyzer measures CO, CO_2, HC, O_2 and NO_X in the exhaust. The range and accuracy of the 5- gas analyzer is given in Table-2.

Figure-1. Experimental setup showing eddy current dynamometer, controller and gas analyzer.

Table-1. Specifications of the engine.

Manufacturer	**Kirloskar Oil Engines Limited, Pune, India**
Model	AVL
Engine type	Vertical, single cylinder, water cooled, 4-stroke, constant speed (1500 rpm), Direct injection, compression ignition engine
Power (rated)	3.67 kW at 1500 rpm
Bore/Stroke	80mm/110mm
Displacement volume	553 cc
Compression ratio	16.5

Table-2. Exhaust gas analyzer.

Exhaust gas	**Measurement range**	**Resolution**	**Accuracy**
CO	0-10% vol.	0.01% vol.	<0.6% vol.: ± 0.03%, ≥0.6%vol.:± 5% of ind. val
HC	0-20000 ppm	≤2000:1 ppm vol. >2000: 10 ppm vol.	<2000 ppm vol.:± 10 ppm ≥2000 ppm vol:± 5% of ind. val.
CO_2	0-20%vol.	0.1 % vol. .	<10%vol.:± 0.5 %vol. ≥10% vol.:± 0.5% of ind. val.
O_2	0-22%vol.	0.01% vol.	<2%vol.: ± 0.1%vol. ≥2% vol.:± 5%of ind. val
NO_X	0-5000 ppm	1 ppm vol.	<500 ppm vol.:± 50 ppm. ≥500 ppm vol:± 10% of ind. val

VOL. 5, NO. 2, FEBRUARY 2010 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences
©2006-2010 Asian Research Publishing Network (ARPN). All rights reserved.
www.arpnjournals.com

RESULTS AND DISCUSSIONS

To determine performance and emission characteristics of the engine, tests were conducted at no load, 33.3%, 66.6% and 100% of rated load. The results of the engine emissions, carbon monoxide (CO), hydrocarbon (HC), carbon dioxide (CO_2), and oxides of nitrogen (NO_x), at 200 bar injection pressure and performance parameters efficiency and BSEC are shown in Figure-2. The emissions are compared with that of diesel. The CO emissions were slightly higher for B20 and B40 blends. HC emissions decreased by upto 12.8 % for B20 and 2.85% B40 compared to diesel at full load. The decrease however was insignificant. The decrease in these emissions can be attributed to the presence of oxygen in biodiesel leading to better utilization of fuel.

Depending on load, the NO_x emissions decreased by 39% for B20 and 28 % for B40. This reduction may be due to better combustion of fuel. Similar results have been reported by Sureshkumar *et al*., [4], Banapurmath *et al.,* [7]. The efficiency decreased by 2.8% for B20 and 2.7% for B40. The BSEC value increased by 7% for B20 and 1.9% for B40. The increase in these two values is due to the decrease in heat input at different blends as the heating value of the blend is less than that of diesel (by 3.28 % for B20 and 6.5% for B40).

The above results indicate that both B20 and B40 blends can be used in diesel engines without any engine modifications.Better emissions and performance characteristics are obtained at a blend of B40.

ECONOMICS OF BIODIESEL

The cost of biodiesel produced from karanja and neat diesel are compared to find the suitability of Karanja (non-edible oil) biodiesel as an alternative fuel to diesel. The yield of karanja seeds for 1000 trees planted at the boundary (10% of area) of 1 hectare field is 1000 kg., with a yield of 250 kg of oil and 750 kg of oil cake. (Remaining 90% area i.e. 0.9 hectare can be used for regular farming). The cake can be used as manure which is equivalent to 325 kg of urea. If wasteland is used for plantation of karanja, then 10,000 kg of seeds are obtained giving 2500 kg of oil and 7500 kg of oil cake per hectare. At the current market price this will give an income of Rs.60, 000 ($ 1225) per hectare. Considering yield of 25% oil from karanja seeds and 4 kg of seeds are required to produce 1 kg of biodiesel, a comparison of the cost of karanja biodiesel is given in Table-3 below for different cost of seeds. From the table it is clear that the cost of biodiesel obtained from karanja oil is much less than that of petroleum diesel. Hence biodiesel of karanja can be a good substitute to diesel leading to savings in foreign exchange for importing and generating employment.

Table-3. Comparison of cost of biodiesel and diesel.

#	**Details cost in $/ Case**	**I**	**II**	**III**
1	Cost of Karanja seeds/kg	0.122	0.163	0.204
2	Cost of 4 kg of seeds	0.488	0.652	0.816
3	Expelling charges for 4 kg seeds	0.122	0.122	0.122
4	Processing charges for 4 kg seeds	0.163	0.163	0.163
5	**Total (2+3+4)**	**0.773**	**0.937**	**1.101**
6	Cost of cake @0.1$/kg, for 3kg	0.3	0.3	0.3
7	Cost of glycerol ($) @1$/kg, for 0.122 kg	0.122	0.122	0.122
8	**Net cost of biodiesel/kg** {5-(6+7)}	**0.351**	**0.515**	**0.679**
9	***Current market price of diesel/kg**	**0.96**	**0.96**	**0.96**

* Rates as on January 2009

The results of the tests prove that methyl esters of karanja (B100) have a good potential of being used as a diesel engine fuel. Use of these fuels will help in reducing the import bill of most of the countries and also makes them self reliant on the energy front. Barren land can be used to cultivate the oil producing plants. The land can be leased to the unemployed youth which will lead to growth in employment and improve the life of the people. A 20 % blending will lead to a saving of about Rs. 100,000 crores ($ 20 billion) in foreign exchange to India.

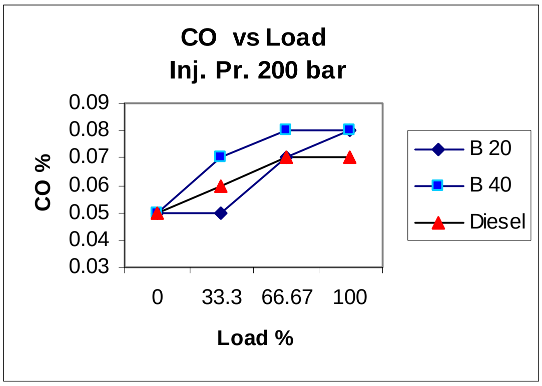
ENVIRONMENTAL BENEFITS

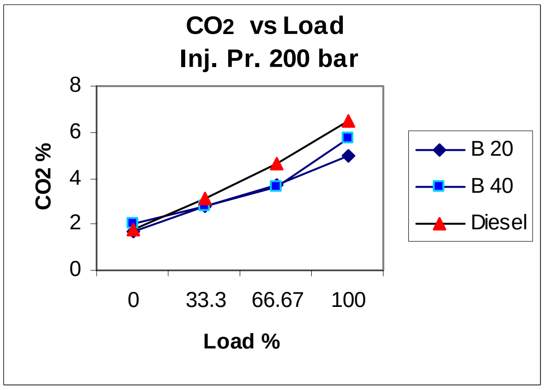
Environmental benefits in comparison to petroleum based fuels include:

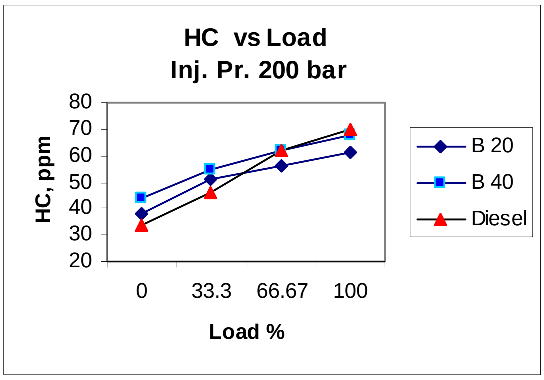
- "At the tailpipe, biodiesel emits more CO_2 than petroleum diesel". However, if "biomass carbon (is) accounted for separately from fossil-derived carbon", one can conclude that biodiesel reduces emissions of carbon monoxide (CO) by approximately 50% and carbon dioxide by 78% on a net lifecycle basis because the carbon in biodiesel emissions is recycled from carbon that was in the atmosphere, rather than the carbon introduced from petroleum that was sequestered in the earth's crust.
- Biodiesel can reduce by as much as 35 % the direct (tailpipe) emission of particulates, small particles of solid combustion products on vehicles with particulate filters, compared with low-sulfur (< 50 ppm) diesel.
- Particulate emissions as a result of production are reduced by around 50%, compared with fossil-sourced diesel.

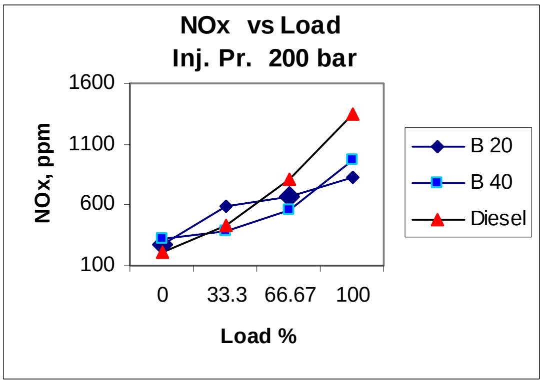
Biodiesel has a higher cetane rating than petrodiesel, which can improve performance and clean up emissions compared to crude petro-diesel (with cetane number lower than 40).

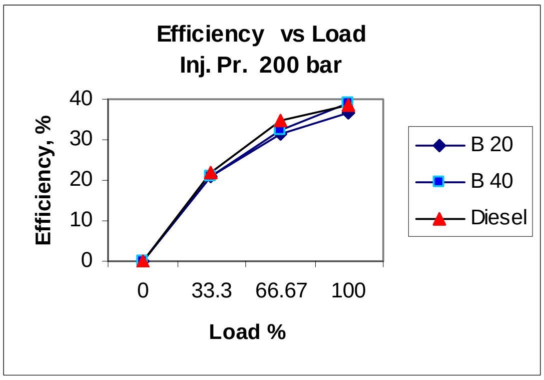
VOL. 5, NO. 2, FEBRUARY 2010 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences
©2006-2010 Asian Research Publishing Network (ARPN). All rights reserved.
www.arpnjournals.com











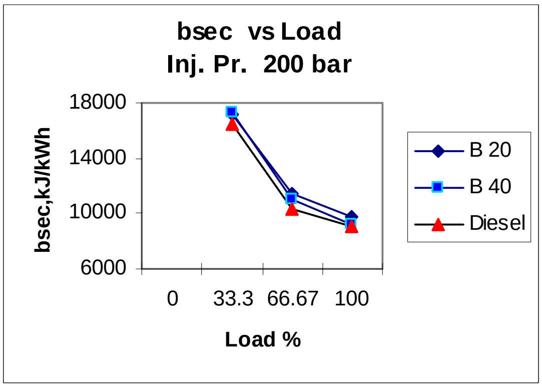


Figure-2. Graphs showing the variation of CO, HC, CO_2, NO_x, efficiency and brake specific energy consumption at different loads at an injection pressure of 200 bar.

CONCLUSIONS

Tests for emission and performance characteristics were conducted on a single cylinder, 4-stroke, constant speed diesel engine at an injection pressure 200 bar. Based on the tests the following conclusions can be drawn:

- At an injection pressure of 200 bar, HC emissions decreased by 12.8 % for B20 and 3 % for B40 at full load. NO_x decreased by 39 % for B20 and 28 % for B40 at full load, BSEC increased by 7 % for B20 and 1.9 % for B40 at full load;
- Hence a blend of 40% biodiesel and 60% diesel (B40) is recommended. There was no significant change in efficiency;
- The results are in line with that reported in literature by different researchers using various biodiesel fuels and their blends; and
- Economic analysis shows that Karanja oil biodiesel can be used in an existing diesel engine without any engine modifications which will lead to employment generation and saving in vital foreign exchange.

©2006-2010 Asian Research Publishing Network (ARPN). All rights reserved.

ACKNOWLEDGEMENTS

The authors would like to thank the Vice Chancellor, University of Pune and Director, Board of College and University Development (BCUD) for funding this study. Thanks are also due to Principal, management and staff of Department of Mechanical Engineering at SRES College of Engineering, Kopargaon for their support during the course of this work.

REFERENCES

[1] Agarwal A.K. 1998. Vegetable oils versus diesel fuel: development and use of biodiesel in a compression ignition engine. TERI Inf Digest on Energy. pp. 191-204.

[2] A.K. Agarwal, L.M. Das. 2001. Bio-diesel Development and Characterization for use as a Fuel in C.I. Engines. Journal of Eng. Gas Turbine Power, ASME. Vol. 123, April.

[3] Sanjib Kumar Karmee *et al*. 2005. Preparation of Biodiesel from Crude Oil of *Pongamia pinnata*. Bioresource Technology. 96: 1425-1429.

[4] K. Sureshkumar *et al*. 2008. Performance and exhaust emission characteristics of a CI engine fueled with Pongamia pinnata methyl ester (PPME) and its blends with diesel. Renewable Energy. 33: 2294-2302.

[5] Recep Altin *et al*. 2001. The Potential of Using Vegetable Oil Fuel as Fuel for Diesel Engine. Energy Conversion and Management. 42: 529-538.

[6] N.R. Banapurmath *et al*. 2008. Performance and emission characteristics of Compression Ignition engine operated on Honge, Jatropha and sesame oil methyl esters. Renewable Energy. 33: 1982-1988.

[7] S.K. Haldar *et al*. 2008. Studies on the comparison of performance and emission characteristics of a diesel engine using three degummed non-edible vegetable oils. Biomass and Bioenergy.

[8] H. Raheman, A.G. Phadatare. 2004. Diesel Engine Emissions and Performance from Blends of Karanja Methyl Ester and Diesel. Biomass and Bioenergy. 27: 393-397.

[9] Sukumar Puhan *et al*. 2005. Performance and Emission Study of Mahua Oil (*Madhuca indica* oil) Ethyl ester in a 4-Stroke Natural Aspirated Direct injection Diesel Engine. Renewable Energy. 30: 1269-1278.

[10] Gvidonas Labeckas *et al*. 2006. The Effect of Rapeseed Oil Methyl Ester on Direct Injection Diesel Engine Performance and Exhaust. Energy Conversion and Management. 47: 1954-1967.

[11] Deepak Agarwal *et al*. 2007. Performance Evaluation of a Vegetable Oil Fuelled Compression Ignition Engine. Renewable Energy. 30.

[12] A.J. Kinney *et al*. 2005. Modifying Soybean Oil for Enhanced Performance in Biodiesel Blends. Fuel Processing Technology. 86: 1137-1147.

[13] Robert G. Pereria *et al*. 2007. Exhaust Emissions and Electric Energy Generation in a Stationary Engine Using Blends of Diesel and Soyabean Biodiesel. Renewable Energy. 32: 2453-2460.

[14] Pramanik. 2003. Properties and Use of Jatropha Curcas Oil and Diesel Fuel Blends in Compression Ignition engine. Renewable Energy. 28: 2339-2348.

[15] Ali Keskin *et al*. 2008. Using of Cotton Oil Soapstock Bio-Diesel Fuel Blends as an Alternative Diesel Fuel. Renewable Energy. 33: 553-557.

[16] Murat Karabektas, Gokhan Ergen, Murat Hosoz. 2008. The effects of preheated cottonessd oil methyl ester on the performance and exhaust emissions of a diesel engine. Applied Thermal Engg. 28: 2136-2143.

[17] Md. Nurun Nabi, Md. Mustafizur Rahman, Md. Shamim Akhter. 2009. Biodiesel from cottonseed oil and its effect on engine performance and exhaust emissions. Applied Thermal Engg. 29: 2265-2270.

[18] M.A. Kalam, H.H. Masjuki. 2002. Biodiesel from palm oil-an analysis of its properties and potential. Biomass and Bioenergy. 23: 471-479.

[19] B.K. Barnwal, M.P. Sharma. 2005. Prospects of Bio-diesel Production from Vegetable Oils in India. Renewable and Sustainable Energy Reviews. 9: 363-378.