Int. J. Environ. Res., 3(3):463-470, Summer 2009
ISSN: 1735-6865

Performance and Emission Evaluation of Diesel Engine Fueled with Vegetable Oil

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Received 25 May 2008; Revised 15 Aug. 2008; Accepted 25 Nov. 2008

ABSTRACT: Various combustion characteristics and properties are studied while selecting a fuel for any engine. The choice of the engine and fuel are highly interrelated. Vegetable oil is one obvious fuel particularly because their fuel properties are closer to diesel fuel. Two important properties, the cetane number and the calorific value are similar to diesel. Hence diesel engines can be operated on vegetable oil without modification. To ascertain the possibility of use of modified karanja oil as fuel for compression ignition engine the performance test were conducted. The comparison of the test fuels made with diesel fuel. Test fuels' performance analyzed for esters of karanja oil, blends of karanja oil, and the diesel oil as baseline at varying loads performed at governor controlled speed. The variations in the injection parameters were analyzed to observe its influence on the engine performance with different fuels. Experimental results show that diesel engine gives poor performance at lower Injection Pressure than esterified karanja oil and its blends with diesel. Specific energy consumption is a more reliable parameter for comparison. MEKO and 50KO which shown comparable energy required per kW power than diesel fuel it may be due to lower calorific value of MEKO. Comparable smoke found for karanja oil methyl ester with that of diesel fuel. Smoke emission increases with increase in engine load due to overall richer combustion, longer duration of diffusion combustion phase and reduced oxygen concentration.

Key words: Engine,Vegetable oil, Karanja oil, Cloud point, Injection Pressure, Exhaust smoke

INTRODUCTION

In 1892, the German scientist Rudolf diesel (1858-1953) outlined in his patent a new form of internal combustion engine. His concept of initiating combustion by injecting a liquid fuel into air heated solely by compression permitted a doubling of efficiency over other internal combustion engines. The desirable properties in a diesel fuel are ignition quality, higher cetane number, sufficient calorific value, lubricity, specific gravity, volatility and viscosity. Whereas cetane number plays the important role governing the suitability of fuel in C. I. engines. Ignition quality of the fuel is given in terms of cetane rating, which is a measure of its ability to auto ignite quickly when injected into the compressed high temperature air in the engine cylinder. Fuels having cetane number 40 and above are suitable for compression ignition engines (Pundir, 2007).The concept of using vegetable oil as a fuel dates back to 1895, when Dr Rudolf diesel, the inventor of compression ignition engine used groundnut (Peanut) oil as a fuel at the Paris Exposition in 1900. In 1916, using the first diesel engine imported into Argentina, Gutierrez tested castor oil as an alternative fuel." In 1944, also in Argentina, Martinez de Vedia described short duration runs with blends of vegetable oils and diesel fuel. The vegetable oils tested included sunflower, linseed, groundnut, cottonseed, and turnip. With the vegetable oils comprising 30 & 70% of the fuel mixture. In an extended run (420 h) with 60:40

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diesels—linseed oil, significant problems with the amount and type of carbon deposits were noted, presaging the experience of later investigators. Different types of vegetable oils to the fuel diesel engine occasionally appeared in the literature up to 1960.many workers reported on the availability and fuel possibility of number of vegetable oils some claimed to have successfully used them in the diesel engine. No major modifications were suggested. The power output and fuel consumption was found to be comparable with that of conventional diesel (Antony & Samaga, 1987).

Use of biodiesel is environmentally neutral. (Gopalkrishnan *et al.*, 1987) Diesel engines are widely used as sources of power in developing areas in tractors, irrigation pumps, village generators, and trucks. As a homegrown fuel, vegetable oils are largely unaffected by world petroleum crises and indigenous production eases foreign exchange concerns. Economic feasibility, however, hinges as much on national food and energy policies and priorities as on production costs (Mooney, 2000). Technical feasibility is more straightforward. On a short-term or emergency basis, many vegetable oils can be used directly as diesel fuel. Use of karanja oil in diesel engine is environmental friendly. Diesel fuel injection parameter affects the smoke exhaust emission (Pundir, 2007). Gasoline additives can lead to the contamination of soil and air (Shahidi Bonjar, 2007; Jafari and Ebrahimi, 2007). Exhaust smoke colour one of the easiest methods to use when trouble shooting an engine for a performance complaint is to visually monitor the colour of the smoke this is particularly true. White smoke is generally most noticeable at the engine starter particularly during conditions of low ambient temperatures when the air drawn in to the engine is cold. Although more dense than warmer air, this cold air will result in lower temperatures and pressures at the end of the pistons compression stroke. Consequently all of the fuel will not burn to completion in the cylinder when the exhaust valves opened, these fuel droplets are exhausted in to the atmosphere as unburned hydrocarbon which cools, condense, and appear as white smoke**.** Black or gray smoke**:** generally, either colour of exhaust smoke is caused by mainly due to the opacity or denseness of smoke less than 5% exhaust smoke opacity is hardly visible to the necked eye. The black or gray smoke is mainly due to the incorrect fuel injection timing, incorrect fuel delivery rate, faulty nozzles or injectors, faulty fuel injection pump. Blue smoke is attributable to oil and entering the combustion chamber and being burn or blown through the cylinder and burned in the exhaust manifold (Heywood, 1988).

MATERIALS & METHODS

Fats and oils are water insoluble hydrophobic substances primarily composed of fatty esters of glycerol (triglycerides). Structurally, a triglyceride is reaction product of one molecule of glycerol with three molecules of fatty acids to yield three molecules of water and one molecule of tri glycerides. The carbon chain length and number of unsaturated bonds varies in fatty acid chain shown in (Table 1). The different national and international standards are given in (Table 2).

The karanja oil when mixed with diesel oil forms a homogeneous mixture. Blending of karanja oil with diesel oil not only drastically brings down the viscosity but also help in refinement of

Table 1. Chemical structure of common fatty acids (Agrawal, 2007)

Fatty acid	Systematic name	Structure	Formula
Lauric	Dodecanoic	12:0	$C_{12}H_{24}O_2$
Myristic	Tetradecanoic	14:0	$C_{14}H_{28}O_2$
Palmitic	Hexadecanoic	16:0	$C_{16}H_{32}O_2$
Stearic	Octadecanoic	18:0	$C_{18}H_{36}O_2$
Arachidic	Eicosanoic	20:0	$C_{20}H_{40}O_2$
Behenic	Docosanoic	22:0	$C_{22}H_{44}O_2$
Lignoceric	Tetracosanoic	24:0	$C_{24}H_{48}O_2$
Oleic	cis-9-Octadecenoic	18:1	$C_{18}H_{34}O_2$
Linoleic	cis-9,cis-12-Octadecadienoic	18:2	$C_{18}H_{32}O_2$
Linolenic	cis-9,cis-12, Cis-15-Octadecatrienoic	18:3	$C_{18}H_{30}O_2$
Erucic	cis-13-Docosenoic	22:1	$C_{22}H_{42}O_2$

Table 2. ASTM D-6751 standards for biodiesel

Flash point (closed cup)	130°C min. (150°C average)
Water and sediment	0.050% by vol., max.
Kinematic viscosity at 40°C	1.9-6.0 mm^2/s
Rams bottom carbon residue, % mass	0.10
Sulfated ash	0.020% by mass, max.
Sulfur	0.05% by mass, max.
Copper strip corrosion	No. 3 max
Cetane	47 min.
Carbon residue	0.050% by mass, max.
Acid number -- mg KOH/g	0.80 max.
Free glycerin	0.020 % mass
Total glycerin (free glycerin and unconverted glycerides combined)	0.240% by mass, max.
Phosphorus content	0.001 max. % mass
Distillation	90% @ 360°C

karanja oil properties to suit the compression ignition engine. The blends of 30%, 50% of Diesel in karanja oil represented as 30KO (karanja oil) & 50KO respectively were prepared. These were then left for few days. The fuel properties such as specific gravity, Kinematic viscosity, flash point, cloud and pour point and calorific value determined for the study. These were determined in the institute laboratory according to the standard procedure of BIS.The specific gravity of MEKO (methyl ester karanja oil) determined by the standard RD (relative density) bottle of 50ml MEKO, separately filled in the bottles. The weights were measured on an electronic balance. The density of methyl ester was calculated.

The viscosity of a fuel is important property, which is affecting the atomization of the fuel during the injection. High viscosity of plant oil was reported to be the main cause of injector chocking problem in C.I. engine. A viscometer used to measure the Kinematic viscosity of diesel fuel, karanja methyl ester and their blends.Flash point of any fuel signifies the temperature at which the fuel self ignites. It was measured using Pensky Martens apparatus.

Cloud point is the temperature where crystal formation in the fuel starts and pour point is the temperature where fuel ceases to flow. These two points were measured by Pensky Martens apparatus.The gross calorific values of the karanja methyl ester, diesel and their blends were determined by Bomb Calorimeter method. A weighted quantity of sample burned in oxygen in Bomb calorimeter under controlled conditions. Rise in temperature recorded the gross calorific value was then calculated from the weight of the sample.

RESULTS & DISSCUSION

Fuel properties have a significant role in the process of evaluation of their suitability for any engine application. Few of the important test fuel properties, determined and they are in the comparable range with diesel fuel. The viscosity measured at 25°C for all the test fuels.The viscosity, as compared to diesel oil, was 8 times, 2.5times, 1.5 times and 1.8 times for karanja oil, MEKO, 30KO and 50KO respectively(Fig.1). The calorific values of karanja oil, MEKO, 30KO and 50KO blends were 84.5%, 88%, 97% and 94% respectively as compared to diesel oil. Similarly the densities of MEKO, 30KO and 50 KO blends were approximately 1.25, 1.1 and 1.2 times respectively of that of diesel oil. The effect of variation in fuel injection parameters with different test fuels was studied(Fig.2).The experiments were conducted at three different fuel injection pressures of 17.0 MPa, 20 MPa and 23 MPa. Constant engine speed of 1500 rpm was maintained by the governor. The test was conducted with increasing BMEP, from 150 KPa to 600 KPa.

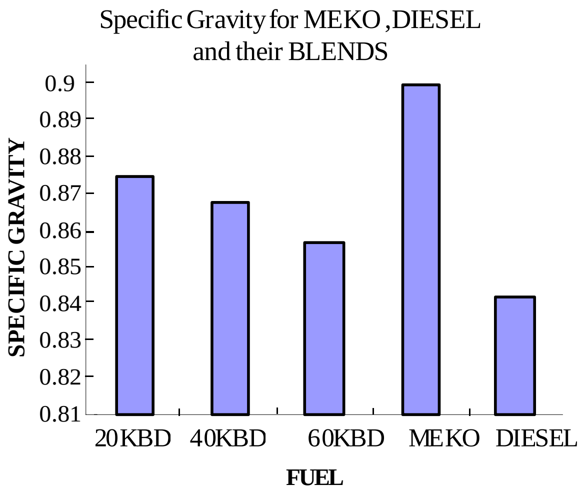

Fig.1. Sp.Gravity of MEKO, DIESEL, and their Blends

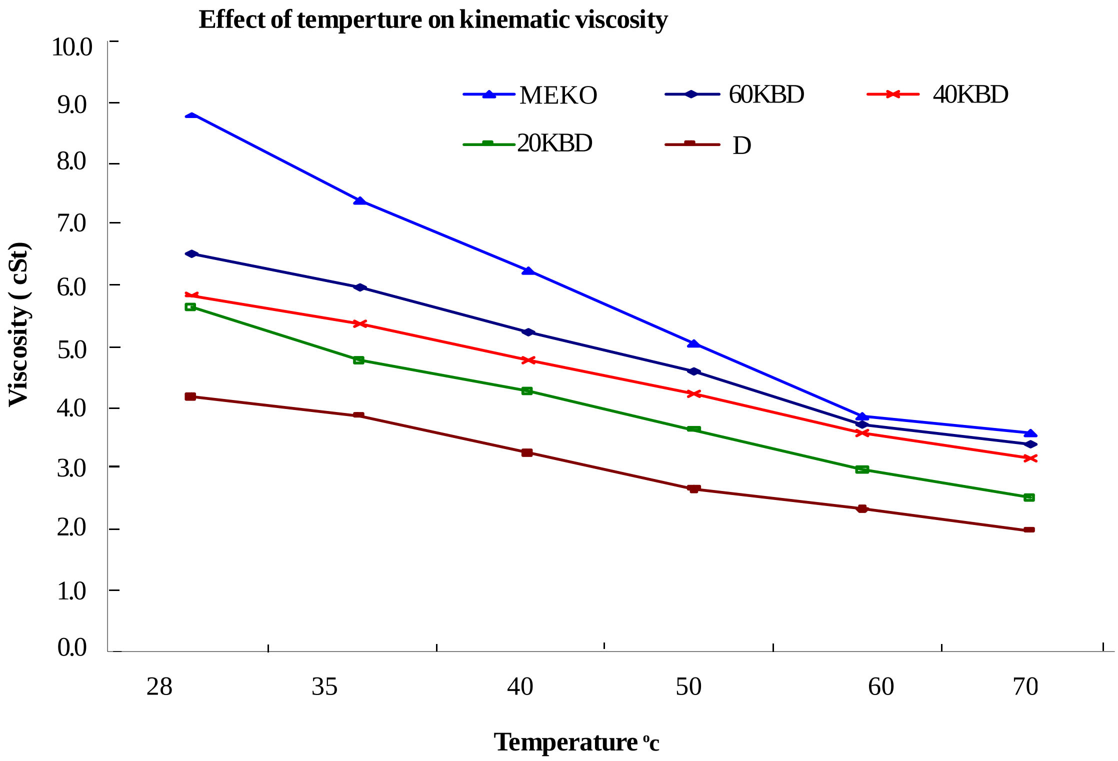

Fig. 2. Effect of temperature on Kinematic Viscosity

Fig. 3. shows the effect of load on engine performance with different fuels with fuel injection at 27° before top dead centre and at 20 KPa pressure. 50% diesel in esters of karanja oil (50KO) and 30% diesel in karanja oil esters (30KO) both show almost similar performance which can be attributed to non optimized fuel injection conditions for the bio-diesel blends. Methyl ester of karanja oil (MEKO) show a performance which has better cetane NO as reported by (Huzayyin *et al.*, 2004) but calorific value is lower as compared to diesel which affects performance. The lowest SEC is 14.3 MJ/kWhr, 15.1MJ/kWhr and 18.1 MJ/kWhr for 50KO, 30KO and MEKO as compared to 11.5 MJ/kWhr for diesel respectively.Fig. 4. shows the comparative changes in SEC for 50 KO, 30 KO and MEKO at fuel injection timing of 27° btc and a lower fuel injection pressure of 17 MPa. Fuel injection pressure affects injected fuel droplet size and pattern of distribution. Pressure being low results into larger droplets due to higher viscosity for alternative fuels.The values have been compared with baseline values obtained with diesel. As compared to minimum SEC obtained with diesel the minimum for 50 KO, 30 KO and MEKO are 14.8MJ/kWhr, 17.2MJ/kWhr and 20.2MJ/kWhr respectively.Fig. 5. shows the variation of SEC at fuel injection timing of 27^0 btc and a higher injection pressure of 23 MPa. As stated the fuel injection pressure affects fuel droplet size distribution of fuel. The values of SEC for 50 KO and 30 KO as evident moved close enough to that obtained for diesel at baseline conditions. The minimum SEC was 13.6 MJ/kWhr, 14MJ/kWhr and 16.8MJ/kWhr for 50 KO, 30 KO and MEKO respectively.

Smoke density in the exhaust depends upon fuel combustion and carbon content of the fuel. Fuel combustion depends upon fuel cetane number, viscosity and density of the fuel. Cetane number indicates fuel response during combustion in CI engine as it is related to fuel self ignition temperature. Self ignition temperature is related to rate of heat release.Higher viscosity and density influences spray pattern, mixing and hence combustion. (Fig. 6). shows the effect of load on exhaust smoke at best injection timing of 31^0btc and pressure 23 MPa. MEKO, 50 KO, and 30 KO have comparable smoke densities with baseline diesel values an injection condition of 27 btdc and 20 MPa. It is evident from the figures. 3 to 6 that with the increase in load on the engine

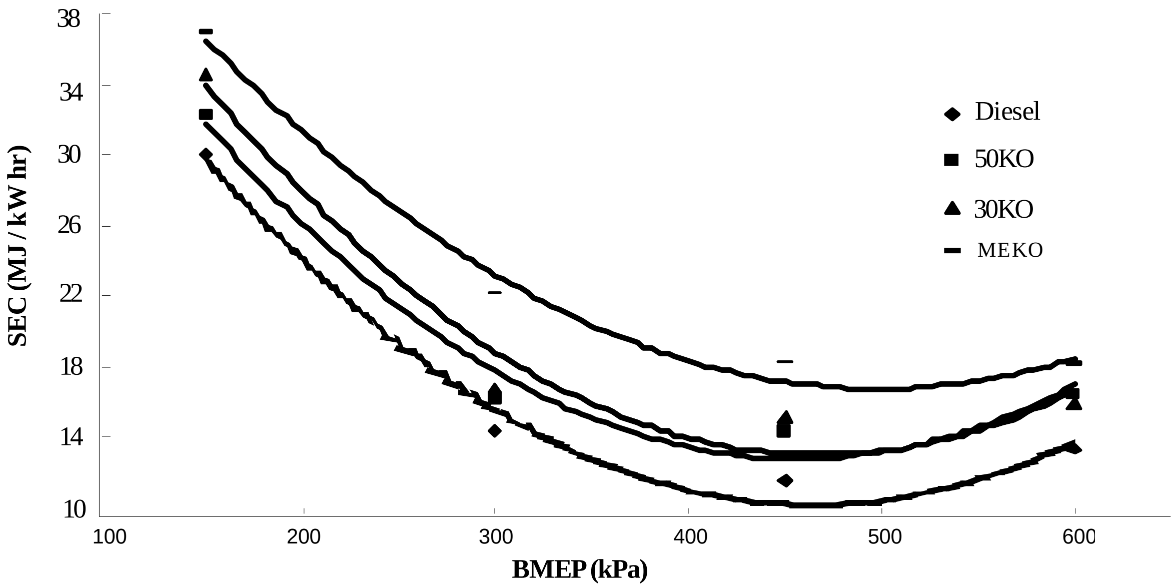

Fig. 3. Effect of load on engine performance with different Fuels with Fuel Injection at 27 BTC.& Fuel Injection Pressure at 20 MPa

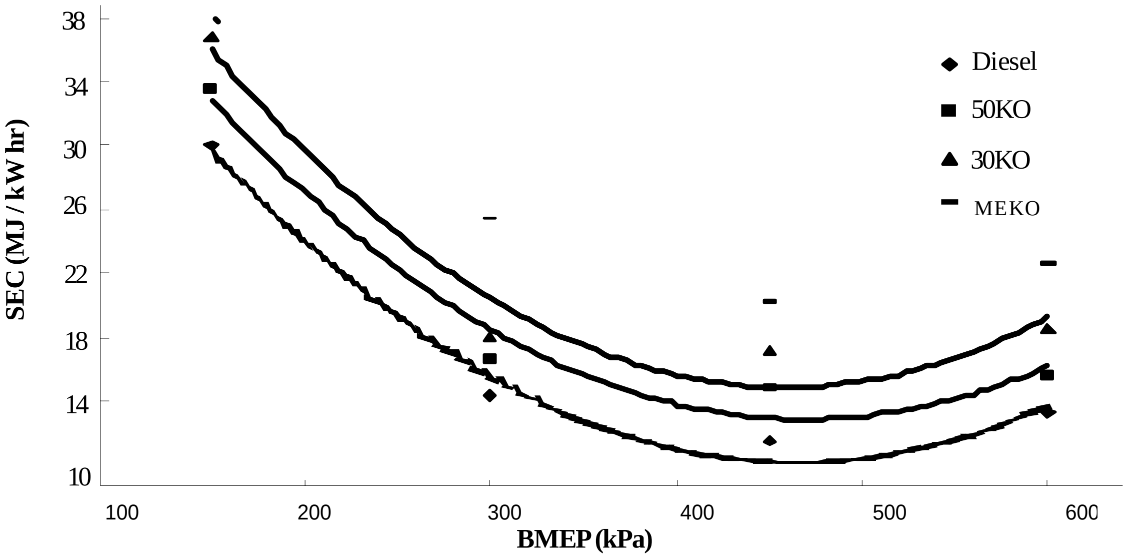

Fig. 4. Effect of load on engine performance with different fuels with injection at 27^0 btdc and fuel injection pressure at 17 MPa

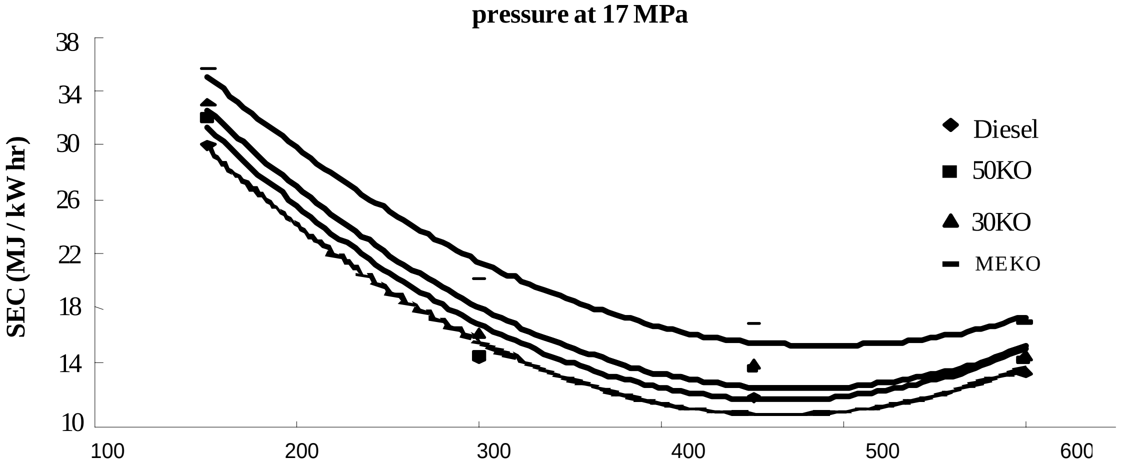

Fig. 5. Effect of load on engine performance with different fuels with injection at 27^0 btdc and fuel injection pressure at 23 MPa

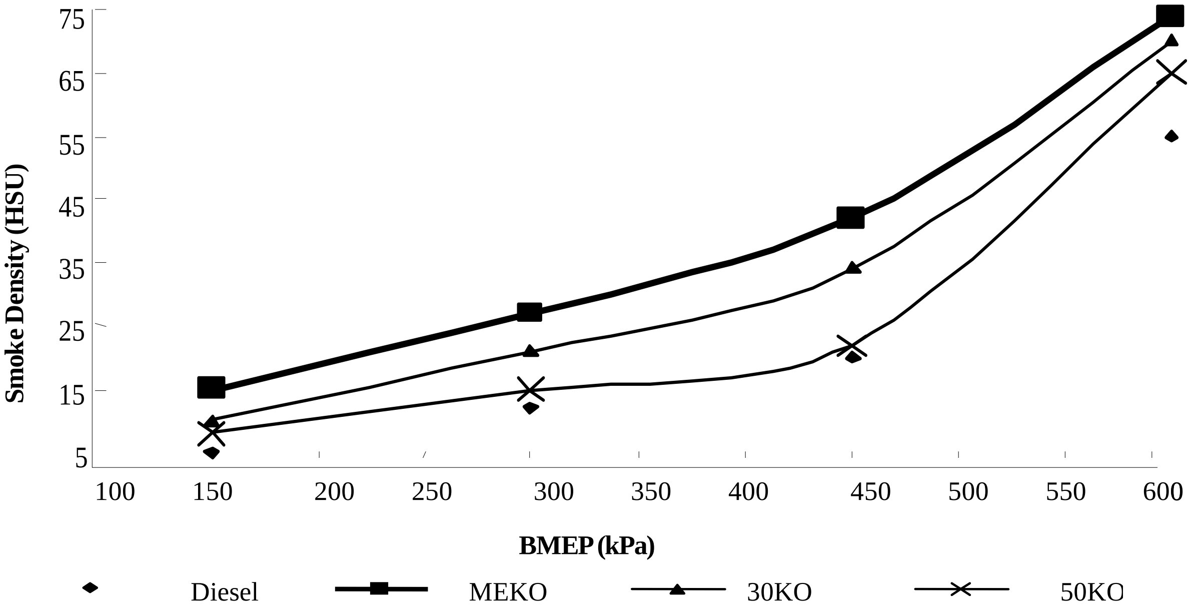

Fig. 6. Effect of load in terms of BMEP on exhaust smoke at injection 31^0 btdc and fuel injection pressure at 23 MPa

the SEC falls and a minimum value is achieved at around 450 KPa with almost all fuel types. It is further evident that minimum SEC is achieved with diesel as convenient fuel as compared to all the test fuels. Further, it is also seen that with the blends of esters in diesel i.e. 30% esters and 50% esters in diesel respectively the SEC has a lower value as compared to MEKO This may be attributed to improved properties of blends being similar to diesel than MEKO.

CONCLUSION

Based on the results of this study following conclusions were drawn:

• Vegetable oil is one such promising fuel for compression ignition engines, which has characteristics very close to diesel. Non edible oil should be used for biodiesel preparation as edible oil is in heavy demand for cooking purpose. A comparison of physical and fuel properties of vegetable oils with those of diesel fuel indicates that the vegetable oil are quite similar in nature to diesel fuel. However, vegetable oils have exceptionally high viscosity. After esterification of karanja oil, the specific gravity reduced to 0.895 at 28^{0}C and for diesel at the same temperature was 0.84. The calorific value of esterified karanja oil found to be 36.76 MJ/kg, which is 17.95% lower than that of diesel.

• Experimental results show that diesel engine gives poor performance at lower Injection Pressure while running on esterified karanja oil and its blends with diesel.

• The specific Energy consumption is higher for pure karanja methyl ester as well as for its blends with diesel. Specific energy consumption is a more reliable parameter for comparison. MEKO and 50KO which shown comparable energy required per kW power than diesel fuel it may be due to lower calorific value of MEKO.

• Comparable smoke found for karanja oil methyl ester with that of diesel fuel. Smoke emission increases with increase in engine load due to overall richer combustion, longer duration of diffusion combustion phase and reduced oxygen concentration. Engine power rating and maximum break mean effective pressure is generally limited by the permissible smoke emission. Poor control of fuel injection rate during acceleration increases smoke can be reduced by reducing the period of diffusion combustion by promoting rapid fuel air mixing achieved through use of high swirl rates, by increasing injection rate of improving fuel atomization. Advancing injection timing increases combustion temperatures and allows more time for oxidation of soot in the expansion stroke thereby reducing smoke emissions.

REFERENCES

Agrawal, A. (2007). Biofuel application as fuel for internal combustion engines. Int. J. progress in energy and combustion sciences, **33,** 233-271.

Alcantara, R. Amores, J., Canoira, L., Fidalgo, E., Franco, M.J. and Navarro, A. (2000). Catalytic production of biodiesel from soybean oil used Frying oil and tallow. Int. J. Biomass and Bioenergy, **18,** 515-527.

Antony, A.J. and Samaga, B. S. (1987, December.). Combustion Analysis in a Compression Ignition engine Using Vegetable Oil. Paper presented in Xth National Conference ICEC, Rajkot.

Babcock, D., Konar, S., Mao, V. and Sidi, H. (1996). Fast one-Phase oil-Rich Processes for the Preparation of Vegetable Oil Methyl Esters. Int. J. Biomass and Bioenergy, **11,** 43-50.

Bhatt, Y. C., Murthy, N. S. and Datta, R.K. (1987 December). Use of Non Edible Oils as Fuel for Diesel Engine. Paper presented in Xth National Conference ICEC Rajkot.

Bose, P. K., Beg, R. A., Ghosh, B.B. and Saha, S.K. (2000). Linseed based Fuel for Diesel Engines. (New Delhi, Narosa Publishing House).

Cardonea, M., Mazzoncinib, M., Meninib, S., Roccoc, V., Senatorea, A.,Seggianid, M. and Vitolod, S. (2003). Brassica carinata as an alternative oil crop for the production of biodiesel in Italy: agronomic evaluation, fuel production by Transesterification and characterization. Int. J. Biomass and Bioenergy, **25,** 623 – 636.

Chuang, W.C., Schumacher, L.G. and Suppes, G. (2004). Impact of cold flow improvers on soybean biodiesel blend. Int. J. Biomass and Bioenergy, **27,** 485–491.

Domkundwar, A. (1999). A Course in Internal Combustion Engines. New Delhi, Dhanpat Rai publication.

Giannelos, P. N., Zannikos, F., Stournas, S., Lois, E. and Aanstopoulos, G. (2002). Tobacco Seed oil as an Alternative Diesel Fuel: physical and chemical properties. Int. J. Industrial crop and products, **16(1),** 1-9.

Ghadge, S., V. and Hifjur, R. (2004). Biodiesel production from mahua oil having high free fatty acids. Int. J. Biomass and Bioenergy, **2,** 185–192.

Goodrum, J. W., Geller Daniel, P. and Adams Thomas, T. (2003). Rheological characterization of animal fats and their mixtures with #2 fuel oil. Int. J. Biomass and Bioenergy **24,** 249 – 256.

Gopalkrishnan, K., Srinivasa, P. and Gopalkrishnan, K. V. (1987 December). Vegetable oil as Diesel Engine Fuel. Paper presented in Xth National Conference ICEC Rajkot.

Griffin Shay, E. (1993). Diesel Fuel from Vegetable Oils: Status and Opportunities. Int. J. Biomass and Bioenergy, **4,** 227-242.

Heywood, J.B. (1988). Internal Combustion Engines Fundamental. India: McGraw-Hill Book Company. Edition.

Huzayyin, A. S. Bawady, A. H., Raddy, M. A. and Dawood, A. (2004). Experimental evaluation of Diesel engine performance and emission using blends of jojoba oil and Diesel fuel. Int. J. Energy Conservation and Management, **45,** 2093-2112.

Jafari, H. R. and Ebrahimi, S. (2007). A Study on Risk Assessment of Benzene as one of the VOCs Air Pollution. Int. J. Environ. Res., **1(3),** 214-217.

Jajoo, B. N. and Keoti, R. S. (2000). Evaluation of Vegetable Oil as Supplementary fuels for diesel Engines New Delhi, Narosa Publishing House.

Kalam, M. A. and Masjuki, H. H. (2002). Biodiesel from palmoil—an analysis of its properties and Potential. Int.J. Biomass and Bioenergy, **23,** 471 – 479.

Kalligeros, S., Zannikos, F., Stournas, S., Lois, E. and Anastopoulos, G. (2003). An investigation of using biodiesel/marine diesel blends on the performance of a stationary diesel engine. Int. J. Biomass and Bioenergy, **24,** 41 – 149.

Karaosmanoglu, F., Kurt, G. and Ozaktas, T. (2000). Long term CI engine test of sunflower oil. Int. J. Renewable Energy, **19,** 219-221.

Kusdiana, Dadan. and Saka, S. (2004). Effects of Water on Biodiesel Fuel Production by Supercritical Methanol treatment. Int. J. Bioresource Technology, **91,** 289-295.

Lele, S.V. (2002). Biodiesel in India. Retrieved, December 10, 2004, from: http://www.svlele.com/Biodiesel in India.html.

Mathur, M. L. and Sharma, R. P. (2000). A Course in Internal Combustion Engines. New Delhi, Dhanpat Rai publication.

Mittelbach, M. (1996). Diesel Fuel Derived from Vegetable Oils, VI: Specification and quality control of biodiesel. Int. J. Bioresource Technology, **56,** 7-11.

Monyem, A. and Gerpen Jon, H. (2001). The effect of biodiesel oxidation on engine performance and emissions. Int. J. Biomass and Bioenergy, **20,** 317–325.

Mooney John, J. (2000). Diesel Engine Emission Control Requires Low Sulpher Diesel Fuel. Int. J. SAE, **1,** 1434.

Muniyappa, P. R., Brammer Scot, C. & Noureddini, H. (1996). Improved Conversion of Plant Oils and Animal Fats into Biodiesel and Co-Product. Int. J. Bioresource Technology, **56,** 19-24.

Pande, K. C., Pande, K. P., Ghosh, B. B. and Ramanunjam, S. (2000). Critical Review on Vegetable Oils as Substitute Fuel for Diesel Engines. New Delhi, Narosa Publishing House Pvt.Ltd.

Pundir, B. P. (2007). Engine emissions. New Delhi, Narosa Publishing House Pvt.Ltd.

Shahidi Bonjar, G. H. (2007). Potential Hazards of Gasoline Additives in Altering Soil Environment in Favor of Harmful Microorganisms. Int. J. Environ. Res., **1(1),** 1-4.