www.sphinxsai.com

ChemTech

International Journal of ChemTech Research
CODEN (USA): IJCRGG ISSN: 0974-4290
Vol.8, No.2, pp 669-675, 2015

Performance and Emission Characteristics of a Diesel Engine using Rubber Seed oil and its Diesel Blends

S. Senthil Kumar[1]* K.Purushothaman[2] & P.K.Devan[1]

[1]Department of Mechanical Engineering, RMK College of Engineering and Technology, Chennai, India
[2]Department of Mechanical Engineering, St Peter's College of Engineering and Tech., Chennai, India

Abstract: In this present work experimental test have been conducted to evaluate the performance and emission characteristics of a diesel engine using the rubber seed oil diesel blends. The properties of neat rubber seed oil like viscosity, volatility and the boiling point are higher than diesel; the rubber seed oil has a lesser cetane number than diesel which prevented the 100% replacement of diesel with the rubber seed oil in the diesel engines. In the present work, rubber seed oil and its blends with petroleum based diesel were tested as a fuel in the diesel engine. The blends were prepared in the proportion of 25%, 50% and 75% rubber seed oil with diesel fuel. The results indicated that the reduction in hydrocarbons, carbon monoxide and smoke emissions were observed and decreased NO emissions compared to with 100% RSO at full load. There is decrease in brake thermal efficiency for all the RSO-diesel blends. It is concluded that the B25 as blend can be used as substitute for diesel fuel with slight decrease in performance and emissions.

Introduction

Diesel engines are considered as the efficient prime movers which are used in various fields such as the transportation sector, power plant and agricultural sectors due to its higher fuel efficiency. But these engines tend to emit toxic emissions to the atmosphere. There is also a risk of quicker depletion of all the fossil fuels. In order to protect the environment from these toxic emissions, increasing cost and fast exhausting of petroleum reserves and to provide a sufficient and continuous supply of energy fuel, it became a necessity to develop alternative fuels such as vegetable oil, alcohol and biomass.

Vegetable oils have comparable energy density, cetane number and heat of vapourization. Also, they are non-toxic and biodegradable with lesser toxic emissions. But they are extremely viscous when compared to the petroleum-based diesel which leads to inadequate fuel atomization and incomplete combustion. The vegetable oils can be modified by blending with petroleum-based diesel in order to reduce the viscosity of the fuel. There are various techniques to reduce the viscosity of vegetable oils such as direct blending, preheating and micro emulsion and transesterification process to convert biodiesel. Martin et al [1-3] reduced the viscosity of vegetable oil by blending it in different proportions with diesel, and analyzed its viscosity at various temperatures and used it as a fuel in a Compression Ignition (CI) engine. They reported that a remarkable improvement in the performance of the engine was noticed.There is a reduction in smoke, CO and HC emissions were also noticed for 60% of cottonseed oil diesel blend.

Bari et al. [4] tested the diesel engine and with preheating of crude Palm oil in a diesel engine. It is found that the crude palm oil started to burn earlier, with a 2.6^{o}C shorter ignition delay, 6% higher peak pressure than diesel combustion and the combustion duration is longer and maximum heat release rate is lower**.** The CO and NOx emissions from the combustion of crude palm oil were higher over the entire load range by an average of 9.2% and 29.3% respectively. Deepak Agarwal et al [5] investigated the effect of linseed oil, mahua oil, and rice bran oil and linseed methyl ester in a diesel engine. They found that brake specific fuel consumptions were higher for vegetable oil compared to diesel fuel. It has been concluded that the 20 % of linseed oil methyl ester blend was optimum that improved the thermal efficiency and reduced the smoke density.

ErkanÖztürk [6] have investigated the performance, emissions, combustion characteristics of a diesel engine fuelled with blends of diesel fuel and a mixture of canola oil–hazelnut soap stock biodiesel diesel blends like 5% (B5) and 10% (B10). The injection and ignition delays and the maximum heat release rates decreased with the biodiesel addition while the injection and combustion durations increased. It is noticed that there is an increased in NO emission and decreased smoke emissions and CO emissions at full load.

Esterification is one of the methods to convert the vegetable oil into its methyl ester, known as biodiesel. Several researchers have used biodiesel as an alternate fuel in the existing CI engines without any modifications [7-8]. Lakshminarayana Rao et al.[9] have studied the combustion analysis of diesel engine with various blends of rice bran oil methyl ester and their results showed that the ignition delay, rate of heat release are decreases also HC and CO emissions are decreased and NO emissions are slightly increased with increase in blends. Suresh Kumar et al studied the performance and emissions of diesel engine with Pongamia pinnatta methyl ester at various blends and they reveal that 40 % blends by volume provide better performance and improved exhaust emissions. Nazar et al [10] have studied the use of coconut oil as an alternative fuel in direct injection diesel engine. It has been reported that the peak thermal efficiency for coconut oil was 28.67% and for diesel. It was 32.51%.It has also been concluded that the smoke, CO, HC and NO emissions were lower than diesel emissions while the exhaust gas temperature was higher than diesel. The objective of the present study is to investigate the performance and emission characteristics of a diesel engine using rubber seed oil diesel blends like B25, B50, B75 and B100 and the results were compared with diesel and neat rubber seed oil (RSO).

2. Material s and Methods

The scientific name of rubber seed is Hevea brasiliensis. The rubber seed contain about 42% oil which is semi drying type. The fresh oil is pale yellow, but the commercial oil obtained from seeds is darker in colour. The colour of oil extracted from fresh seed is brighter than that of stored seed. This variation in the colour is due to degradation of rubber seed with time. From the Gas Chromatography test, the major constituents of rubber seed oil are identified asPalmitic (0.2%), Stearic (8.7%), Oleic (24.6%), Linoleic (39.6%), Linolenic (16.3%) and Linolenic fatty acids (16.3%).The Rubber Seed Oil (RSO) has been used in direct injection diesel engine in the form of Rubber Seed Oil (RSO) blends since it has lower cetane number than diesel. Table 1 shows the properties of rubber seed oil and diesel. It can be understood that the properties of rubber seed oil are comparable with diesel. Table 2 shows the properties for various blends of rubber seed oil – diesel blends. With the increase in the rubber seed oil percentage in the diesel blends, the viscosity and specific gravity increases and the calorific values are decreases.

Table 1. Properties of diesel and Rubber seed oil

Properties	Diesel	Rubber seed oil
Molecular Weight	144	274
Density (kg/m^3)	836	933
Kinematic Viscosity (cSt)	3.97	6.02
Calorific Value (kJ/kg)	42704	33522
Flash Point ^oC	63	71
Pour Point ^oC	21	14
Cetane Number	55	43

3. Experimental Setup

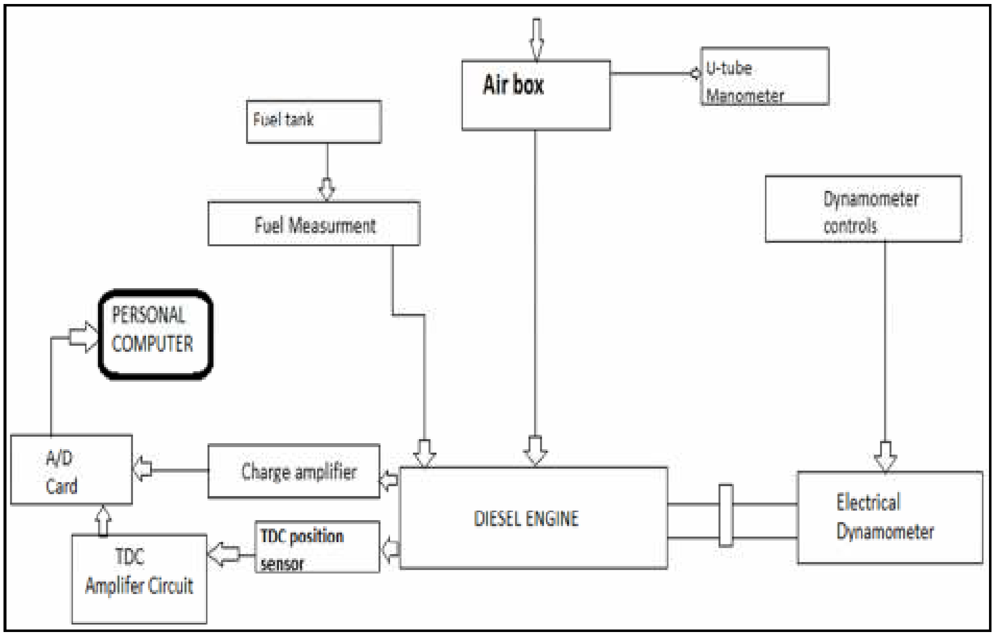

Fig.1 Schematic diagram of experimental setup

Table 3. The specifications of the test engine

Model	Kirloskar, AV 1
Type	Four stroke single cylinder, vertical air cooled Diesel engine
Maximum brake power	4.4 KW
Rated speed	1500 rpm
Bore Diameter	87.5 mm
Stroke (L)	110 mm
Compression Ratio	17.5 : 1
Injection timing	23 ^{o}bTDC

Single cylinder four stroke vertical air cooled diesel engine was used to measure the characteristics of the Rubber Seed Oil - Diesel blends. This engine was coupled to the electrical loading with the control system. Fig.1 shows the schematic diagram of the experimental setup. The rated engine load measured was found to be 28.06 Nm at 1,500 rpm and the corresponding rated power developed by the engine was4.4 kW. The specifications of the test engine are given in the Table 2. By varying the engine load, the tests were conducted at the time interval of 10 mins. The fuel consumption, engine torque, and exhaust gas temperature were measured and performance parameters such as brake specific fuel consumption (BSFC), brake thermal efficiency (BTE) were calculated. The exhaust emissions from the engine such as CO, hydrocarbon (HC), and oxides of nitrogen (NOx) were measured using the AVL-444 Di- gas analyser and Bosch smoke meter. The cylinder pressure was measured with the help of AVL Indi meter data acquisition system. This experiment was done to choose a suitable blend by comparing the performance and emissions of various blends with those of petroleum-based diesel.

4. Results and Discussion

4.1 Brake thermal efficiency

The Figure 2 shows the variation of brake thermal efficiency for different blends of RSO with brake power. . The viscosity of RSO is reduced by blending with diesel fuel. The maximum BTE obtained for diesel, B25, B50, B75 and B100 is 28.64%, 27.74%, 26.82 and 26.2% respectively and with diesel it is 29.92% with full load. It is observed that the RSO-diesel blends showed poor thermal efficiency compared to diesel because of high viscosity and low volatility and leads to poor atomization and vaporization of the RSO fuel. The BTE of B25 is higher compared with all RSO-diesel blends. The BTE of B25 is 4% lesser and 7% higher than diesel and 100% RSO respectively at full load. This may be due to improved viscosity and density of B25 when blend with diesel resulting in better combustion and hence increased brake thermal efficiency.

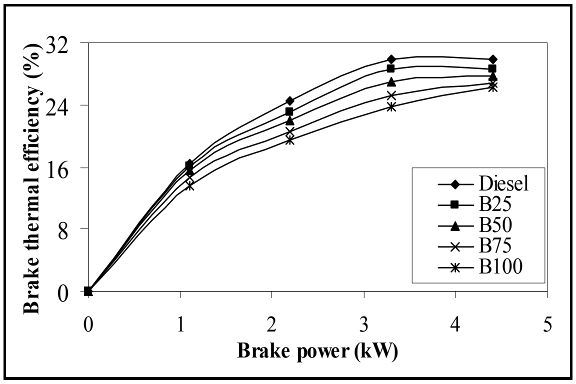

Fig 2. Variation of Brake thermal efficiency with BP

4.2 Brake specific energy consumption (BSEC)

The variation of brake specific energy consumption BSEC with load is depicted in Figure 4. The BSEC for B25, B50, B75 and B100 is 12.9 MJ/kWh, 13.24 MJ/kWh, 13.62 MJ/kWh and 14.0MJ/kWh respectively, whereas for diesel it is 12.4 MJ/kWh at full load. The BSEC for B25 blend is lower compared to diesel and all RSO-Diesel blends at full load. This may be due to lower blend having low viscosity and density which results in better mixture formation and hence improved combustion. By increasing the concentration RSO with diesel blend, the viscosity and density increases, which affect the mixture formation, resulting in poor combustion and hence higher energy consumption.

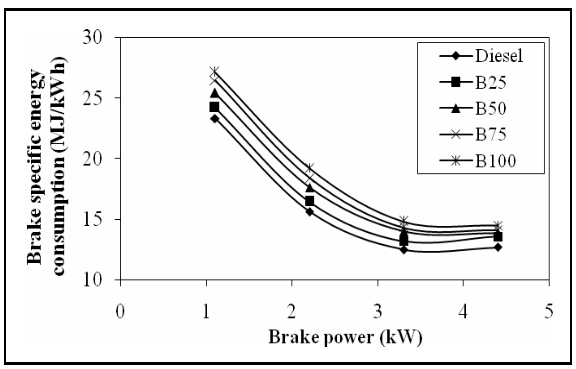

Fig 3. Variation of Brake Specific Energy Consumption

4.3 Exhaust gas temperature (EGT)

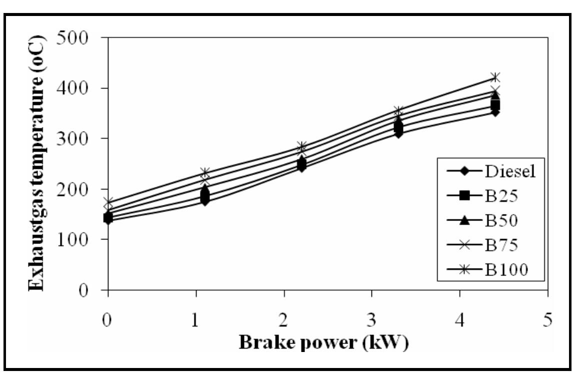

Fig 4. Variation of Exhaust gas temperature with BP

The Figure 4 shows the variation of exhaust gas temperature with brake power. The EGT is increased with the increase in engine loading and also the concentrations of RSO in diesel blends. It is observed that exhaust gas temperature of RSO-diesel blends is higher than diesel at all the loads. This may be due to incomplete combustion of the injected fuel and part of the combustion extending into the exhaust stroke and there is a marginal increase in exhaust gas temperature with RSO-diesel blends. At maximum power output exhaust gas temperature with neat RSO is and for diesel it is 352°C. As the RSO concentration increases in the RSO-diesel blend, there is an increase in exhaust gas temperature at all loads. The maximum exhaust gas temperature of B25, B50,B75 and B100 IS 365°C, 386°C, 394°Cand 420°C respectively at full load. The increase in exhaust gas temperature may be due to need more amount of fuel was required to develop the same amount of power resulting in slower combustion of high viscous RSO-diesel blends and hence the EGT increased with the increase in engine loading. The B25 blend having lower exhaust gas temperature at full load compared to all RSO-diesel blends.

4.4 Carbon monoxide emission (CO)

The variations in carbon monoxide emission with brake power for all the tests fuels are presented in Figure 5. It is found that the CO emission is increased with an increase in proportion of RSO and its diesel blends at all loads. The CO emission with diesel and B25 and B100 are 3.44g/kWh and 4.64g/kWh respectively and for diesel it is 2.95g/kWh at full load. The increase in CO in the case of RSO-diesel blend may be due to poor spray characteristics of RSO and hence improper mixing, resulting in poor combustion. The CO emission increases with increase in the concentration of RSO in the diesel fuel. The higher percentages of RSO in diesel blend deteriorate the performance of the engine due to poor mixture formation. It is observed that there is 70% decrease in CO emission for B25 blend compared with B100 at full load and it produces 17 % higher CO emission than diesel fuel.

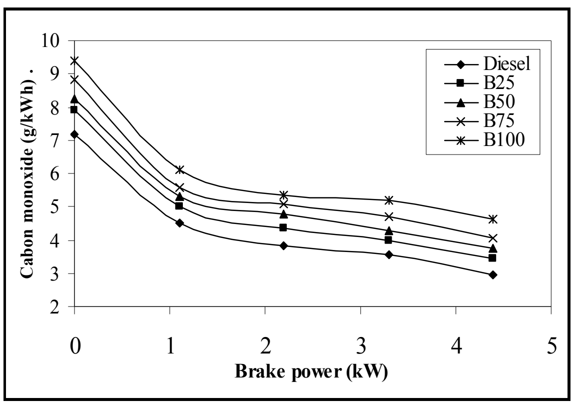

Fig.5 Variation of Carbon monoxide with BP

4.5 Hydrocarbon emission (HC)

The Figure 6 illustrates the variations in hydro carbon emission with brake power compared with diesel. The HC emission also increases with the increase in loading and increase in percentage of RSO in the diesel blend. It is noticed that higher HC emissions obtained for all RSO-diesel blends compared to diesel. At maximum power out put the HC emission for B25 and B100 are 0.59 g/kWh and 0.68 g/kWh respectively and for diesel is 0.55 at full load. This increase in HC emission due to higher viscosity of RSO leads to larger size fuel droplets hence a non uniform distribution with air, which will lead to too rich pockets that can result in hydro carbon emission. Further the HC emission increases with an increase in blending ratio of RSO at all loads. The B25 blend results in an acceptable drop in HC emissions of 0.3 g/kWh at full load, which is lower compared to neat RSO. This indicates better mixture preparation and combustion with the B25 blend.

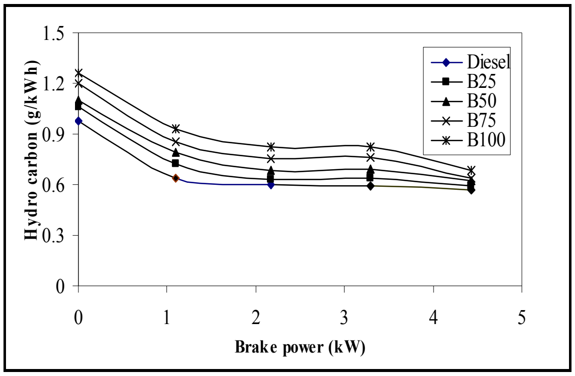

Fig.6 Variation of Hydrocarbon with BP

4.6 Nitrogen Oxide emission (NO)

The variation of NO n with brake power for all fuels is given in Figure 7. The NO emission increases with an increase in engine load due to increase in average gas temperature in the combustion chamber and hence the increase in NO emission for all tests fuels. The NO emission for the B25, 100%RSO operation is 10.2 g/kWh and 6.5 g/kWh respectively and for diesel it is 11 g/kWh at full load. This reduction in NO with RSO operation is due to the lower intensity of premixed combustion compared with diesel. The NO emissions decreases as the amount of RSO increases in the diesel blend. The NO emission of B25 is decreased by 7% compared with diesel fuel.

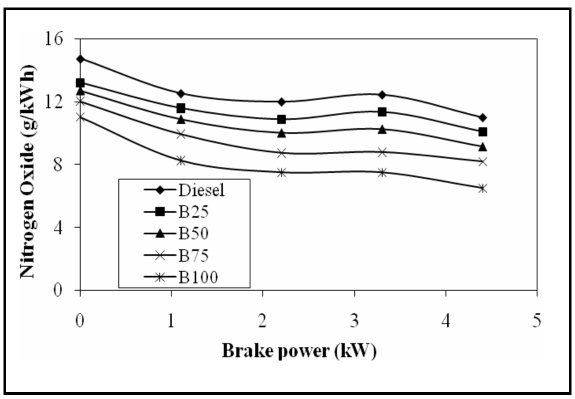

Fig 7. Variation of nitrogen oxide with BP

4.7 Smoke opacity

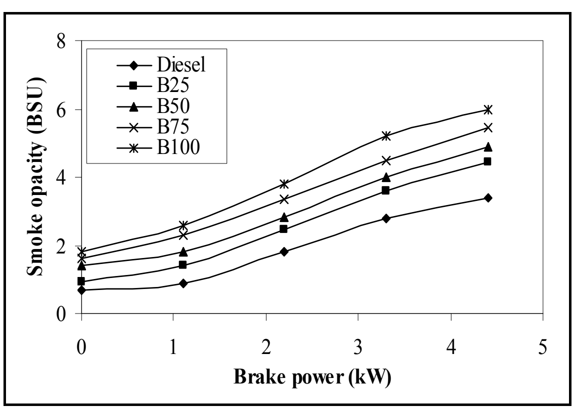

Fig 8. Variation of Smoke opacity with BP

Figure 8 shows the variation of smoke with brake power for the different blends of RSO and diesel. The vegetable oils emit considerable smoke emissions due to their high viscosity. It is observed that, at maximum power output, the smoke density is 4.4 BSU and 6 BSU with B25 and 100%RSO and 3.4 BSU with diesel. This increase in smoke density for RSO and its blend may be due to the heavier molecular structure and higher viscosity of RSO which results in poor atomization and this leads to larger droplet sizes consequently sluggish combustion. Smoke level increases by increasing the percentage of RSO with diesel fuel. The B25 blend reduces the smoke level from 6. BSU to 4.4 BSU at full load. This is because of decreased viscosity of the blend which results in better mixture formation leads to better combustion.

Conclusion

In the present work, experiments were conducted with rubber seed oil and its diesel blends in a four stroke single cylinder constant speed diesel engine at different load conditions. The following are the conclusions drawn based on this experimental work.

- Engine operation with the optimum blend of RSO (B25) and diesel results in better performance than 100% RSO and other RSO blends. The brake thermal efficiency of B25 is increased by 7% than compared with 100% RSO at full load.
- The Exhaust gas temperature is higher with all blends of RSO at full load as compared to diesel due to slow combustion of vegetable oil.
- Both CO and HC emission are found to be high for RSO and its blend at full load. The CO and HC emission for the optimum blend of B25 are 3.4 g/kWh and 0.59 g/kWh respectively.
- The NO emissions for the optimum blend B25 operation is 10.2g/kWh diesel at full load and it is 7% lower than diesel fuel. The smoke density for the optimum RSO blend B25 is reduced to 4.4 from 6 BSU with 100% RSO. The smoke lever of B25 is 29% higher than diesel fuel at full load.
- On the whole, it is concluded that the optimum RSO-Diesel blend B25 can be used as fuel in a compression ignition engine without any modifications with slight decrease in performance of the engine.

References

1. Rosca R, Zugravel M. The use of sunflower oil in Diesel engines. SAE Transactions.,1997, Paper No. 972979: 105–111.
2. Lapuerta M, Armas O, Rodriguez-Fernandez J. Effect of bio-diesel fuels on diesel engine emissions. Progress in Energy & Combustion Science., 2008, 34: 198–223.
3. Pramanik K. Properties and use of Jatropha curcas oil and diesel fuel blends in compressionIgnition Engine. Renewable Energy., 2003, 28: 239–248.
4. Bari S, Lim TH, Yu CW. Effects of preheating of crude palm oil (CPO) on injection system, performance and emission of a diesel engine. Renewable Energy., 2002, 27(3): 339-351.
5. ErkanÖztürk. Performance, emissions, combustion and injection characteristics of a diesel engine fuelled with canola oil–hazelnut soapstock biodiesel mixture. Fuel Processing Technology., 2015, 129: 183–191.
6. Deepak Agarwal, Shailendra Sinha, Avinash Kumar Agarwal. Experimental investigation of control of NOx emissions in biodiesel-fueled compression ignition engine. Renewable Energy., 2006, 31: 2356-2369.
7. Suresh Kumar KR, Velraj R, Ganesan R. Performance and Exhaust emission characteristics of a CI engine fueled with Pongamia pinnata methyl ester and its blends with diesel. Renewable energy., 2008, 33: 2294-2302.
8. Rajan K, Senthil Kumar KR. Performance and Emission Characteristics of Diesel Engine with Internal Jet Piston using Bio diesel. International Journal of Environmental Studies., 2010, 67 (4): 556-567.
9. Lakshmi Narayana Rao G, Saravanan S, Sampath S. Rajagopal K. Combustion and emission characteristics diesel engine fuelled with rich bran oil methyl ester and its diesel blends.Thermal Science., 2008, 12(1): 139-150.
10. Nazar J, Ramesh A. Nagalingam B. Performance and emission characteristics of a diesel engine using coconut oil and its methyl ester. ISTE National Conference on alternate fuels for automobiles, IRTT, Erode, 2004: 24-31.

*****