Performance Characteristics of Four Stroke Diesel Engine Using Bio Diesel Obtained From Rubber Seed Oil

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Abstract

Increase in energy demand, stringent emission norms and depletion of resources led to the discovery of alternative fuels for internal combustion engines. Many alternative fuels like alcohol, bio-diesel, Liquid Petroleum Gas (LPG), Compressed Natural Gas (CNG), etc. have been already commercialized in the transport sector. In the present work, Rubber Seed oil is blended with diesel and used as an alternate fuel for CI engines. The Rubber Seed oil can be converted into bio-diesel using a chemical process called trans-etherification. Different proportions of fuel blends have been produced by the process of blending. The fuel properties of each blend are determined .The load test was conducted on Four Stroke Diesel engine using the blends of rubber seed oil mixed with diesel. The performance parameters such as Power, Specific Fuel Consumption, Thermal Efficiencies, Mechanical Efficiency and Mean Effective Pressures are calculated based on the experimental observations of the engine and compared for different blends. The comparative graphs are drawn at different loads. The sustainability of using alternate fuels in Diesel engines, especially the potential use of Rubber Seed oil as bio-diesel have been brought to the fore through this work.

Keywords: Biodiesel, trans-esterification, rubber seed oil, performance characteristics.

1 Introduction

Biodiesel is a clean burning alternative fuel produced from domestic, renewable resources. The fuel is a mixture of fatty acid alkyl esters made from vegetable oils, animal fats or recycled greases. Where available, biodiesel can be used in compression-ignition (diesel) engines in its pure form with little or no modifications .Biodiesel is simple to use, biodegradable, nontoxic and essentially free of sulphur and aromatics. It is usually used as a petroleum diesel additive to reduce levels of particulates, carbon monoxide, hydrocarbons and toxics from diesel-powered vehicles. When used as an additive, the resulting diesel fuel may be called B5, B10 or B20, representing the percentage of the biodiesel that is blended with petroleum diesel.

Biodiesel is produced through a process in which organically derived oils are combined with alcohol (ethanol or methanol) in the presence of a catalyst to form ethyl or methyl ester. Biodiesel can be made from any vegetable oil, animal fats, waste vegetable oils, or microalgae oils .Biodiesel can be blended in any proportion with mineral diesel to create a biodiesel blend or can be used in its pure form. Just like petroleum diesel, biodiesel operates in the compression ignition (diesel) engine, and essentially requires very little or no engine modifications because the biodiesel has properties similar to mineral diesel. It can be stored just like mineral diesel and hence does not require separate infrastructure. The use of biodiesel in conventional diesel engines results in substantial reduction in the emission of unburned hydrocarbons, carbon monoxide, and particulates. There are currently a large number of existing biodiesel production plants globally, and a large number under construction or planned to supply the growing global demand.

2 Literature Review

A brief study on papers related to Performance Analysis of Compression Ignition Engine using Biodiesel was done. Many authors portrayed different ideas related to their works on Biodiesel. The different papers reviewed are listed below:

Hamed M. El-Mashad et al. investigated on Salmon oil, a by-product of salmon processing, was used as a feedstock for biodiesel production via transesterification in a two-step process. It was found that due to the high acid value of salmon oil, alkaline catalysed transesterification was not an effective method for producing biodiesel from the salmon oil. Therefore a two-step process was applied, in which a sulphuric acid-catalysed pre-treatment was used in the first step to reduce the acid value from 12.0 to 3mg and then, in the second step, KOH-catalysed transesterification was applied. Based on the total weight of salmon oil used, the maximum biodiesel yield of 99% was achieved using a total methanol/molar ratio of 9.2% and 0.5% (w/w) KOH. A preliminary economic analysis showed that the cost of biodiesel production from salmon oil was almost twice that produced from soybean oil.

Piyanuch Nakpong et al. investigated the production of biodiesel from three mixtures of vegetable oil and used cooking oil by alkali catalysed transesterification. Three kinds of vegetable oils, including jatropha, roselle and coconut oils were tested. The effect of used cooking oil content in oil feedstock (used cooking oil/vegetable oil ratios of 0.03-0.2 v/v) on methyl ester formation was investigated and optimized. The methyl ester content from each reaction condition was determined by gas chromatography (GC). The optimum used cooking oil/vegetable oil ratio was 0.03 v/v for all three kinds of oil feedstock.

Avinash Kumar Agarwal et al. reported the technical feasibility of using straight vegetable oils (Jatropha oil), into a constant speed direct injection compression ignition engine. Vegetable oils have very high viscosity, which make their direct usability in engines questionable. In this investigation, SVO's were preheated by using waste heat from engine exhaust, in order to reduce their viscosity. The effect of using these oils on typical engine problems such as injector coking, piston ring sticking, lube oil dilution etc. was investigated in detail. Long-term endurance test (For a duration of 512 hours) of SVO fuelled engine vis-a-vis mineral diesel fuelled engine was executed and the results are compared.

K. Anbumani and Ajit Pal Singh et al. observed the feasibility of using two edible plant oils mustard and neem as diesel substitute a comparative study on their combustion characteristics on a C.I. engine were made. Oils were esterified (butyl esters) before blending with pure diesel in the ratio of 10:90, 15:85, 20:80 and 25:75 by volume. Pure diesel was used as control. Studies have revealed that on blending vegetable oils with diesel a remarkable improvement in their physical and chemical properties were observed. Cetane number came to be very close to pure diesel. Results have indicated that engine run at 20% blend of oils showed a closer performance to pure diesel. However, mustard oil at 20% blend with diesel gave best performance as compared to neem oil blends in terms of low smoke intensity, emission of HC and NOx. All the parameters tested viz., total fuel consumption, specific energy consumption, specific fuel consumption, brake thermal efficiency and cylindrical peak pressure were improved. These studies have revealed that both the oils at 20% blend with diesel can be used as a diesel substitute.

G Lakshmi Narayana Rao et al. Trans esterified vegetable oils (biodiesel) are promising alternative fuel for diesel engines. Used vegetable oils are disposed from restaurants in large quantities. But higher viscosity restricts their direct use in diesel engines. In this study, used cooking oil was dehydrated and then Trans esterified using an alkaline catalyst. The combustion, performance and emission characteristics of Used Cooking oil Methyl Ester (UCME) and its blends with diesel oil are analysed in a direct injection C.I. engine. The fuel properties and the combustion characteristics of UCME are found to be similar to those of diesel. A minor decrease in thermal efficiency with significant improvement in reduction of particulates, carbon monoxide and un burnt hydrocarbons is observed compared to diesel. The use of Transesterified used cooking oil and its blends as fuel for diesel engines will reduce dependence on fossil fuels and also decrease considerably the environmental pollution.

From the above literature survey, the authors have identified some of the gaps in the areas of Biodiesel. Hence the authors have embarked to study the influence of Alternative Fuels. In this paper, the Performance of Compression Ignition Engine using Rubber seed oil as Biodiesel is carried out by following the experimental procedure.

3. Preparation of Biodiesel from Rubber Seed Oil

Initially, oil is filtered from suspended particles and poured in a beaker. For removal of water particles in the oil, it is placed on electrical heater and heated till 100 degrees centigrade is attained so that the water particles present in oil gets evaporated and oil gets cleaned. After than the oil allowed to cool for some time till the room temperature is attained.

3.1 Trans-esterification Process

- In this, fatty acids (esters) present in the rubber seed oil is converted into required biodiesel in the presence of a acid based or base based catalyst.
- First 500 ml of purified rubber seed oil is taken in the conical flask and methanol, sulfuric acid is added in required quantities then fitted with air tight rubber cork along with thermometer.
- Then the conical flask is placed on the heater along with magnetic stirrer. Now heating is carried out with uniform stirring for two hours below 55 degrees centigrade because after 55 degrees centigrade methanol evaporates and escapes in the form of vapor.
- Then sodium hydroxide pellets and methanol is taken in required quantities in other flask and stirred until the pellet particles are completely dissolved in methanol.
- With the help of funnel and filter paper this sodium hydroxide is poured into oil solution and again heated below 55 degrees centigrade till the separation of layer is visible to our eye.

3.2 Draining of Glycerol from Biodiesel

- After stirring, the solution is poured into the separating funnel and is allowed to settle for 8 hours. A major part of the separation takes place in the first hour after the reaction and so a separation progress can be seen. Within 8 hours the glycerol will fall to the bottom of the separating funnel and the layer above glycerol is methyl esters which is lighter in colour than the bottom layer. The bottom layer comprises of glycerol, sodium hydroxide and methanol.
- The stopcock at the bottom of the separating funnel drains the glycerol out in a container. When the glycerol is fully drained the valve is shut.
- The glycerol left in the biodiesel sample comprises of soap which emulsifies when hot water is poured and forms a milky layer which is drained through the stopcock.
- In this process, glycerol is the by-product which is mainly used for soap manufacturing.

Fig. 1 Heating of Oil to remove Water Particles

Fig. 2 Sedimentation of Glycerol and Biodiesel

4 Experimentation

- Check the fuel and lubricating oil systems before staring the engine.
- Connect the water supply to the engine and brake drum and remove all loads on the brake drum.
- Keep three way cock in horizontal position so that fuel flows from the tank to the engine filling the burette.
- Start the engine by hand cranking and allow the engine to pick up the rated speed.
- Allow the engine to run for some time in idle condition.
- Pull the 3 way cock in vertical position and measure the fuel consumption rate by noting the time for 10cc of fuel flow.
- Experiment repeated at different loads.
- Engine is stopped after detaching load from the engine.

4.1 Basic data

1. Rated brake power of the engine B.P = 5 H.P =3.77KW

2. Speed of the engine N = 1500RPM

3. Effective radius of the brake drum R=0.213 m.

4. Stroke length L =110×10^{-3} m

5. Diameter of cylinder bore D = 80×10^{-3} m

6. Time taken for 10cc fuel consumption is ‘t’ sec

4.2 Model Calculations:

Considering B20 blend at 1.8 kgf load:

Specific gravity is 0.815 gm/cc

Calorific value is 42969.7 KJ/kg

Brake Power (B.P) = $\frac{2\pi N(W-S)\times9.81\times R}{60000}$

$$=\frac{2\pi\times1500\times1.8\times9.81\times0.213}{60000}$$

=0.5908 KW

Fuel Consumption (F.C) = $\frac{10}{t}\times\frac{specific\ gravity\times3600}{1000}$ kg/hr

$=\frac{10}{73.2}\times\frac{0.815\times3600}{1000}$ kg/hr

=0.39934 kg/hr

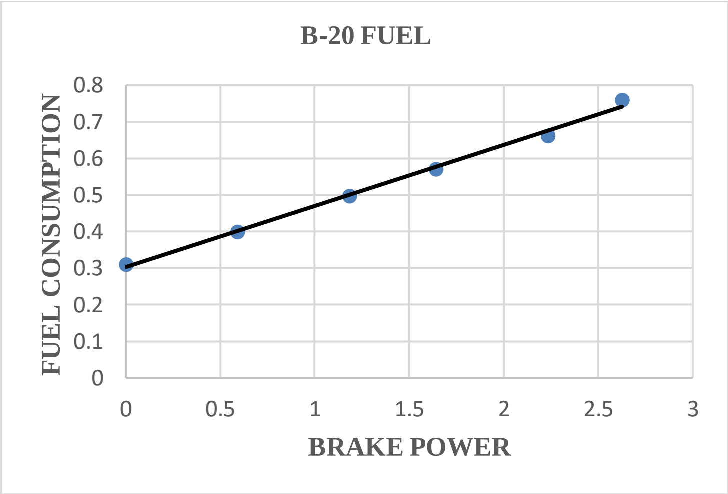

Fig 3 Willians Line method:

Frictional Power from graph (F.P) = 1.5 KW

Indicated power (I.P) = B.P +F.P = 0.5908+1.5 KW

= 2.0908 KW

Specific fuel consumption (SFC) = $\frac{F.C}{B.P}$ kg/KW.hr

= 0.675 kg/KW hr

Brake thermal efficiency η_{Bth} = $\frac{B.P\times3600}{FC\times CV}$

= 12.3%

Indicated thermal efficiency η_{Ith} = $\frac{I.P\times3600}{FC\times CV}$

= 43.86%

Mechanical efficiency η_{mech} $=\frac{B.P}{I.P}$

= 28.2%

Indicated mean effective pressure (IMEP) = $\frac{I.P\times60000}{L\times\frac{\pi}{4}D^2\times\frac{N}{2}}$ N/m^2

= 302500 N/m^2

= 3.025 bar

Brake mean effective pressure (BMEP) = $\frac{B.P\times 60000}{L\times\frac{\pi}{4}D^2\times\frac{N}{2}}$ N/m^2

= 85480.73 N/m^2

= 8.54 bar.

Frictional mean effective pressure (FMEP) = $\frac{F.P\times 60000}{L\times\frac{\pi}{4}D^2\times\frac{N}{2}}$ N/m^2

= 2.17 bar.

5 Results and Discussions

5.1 Performance characteristics of load tests:

The values of brake power, mechanical efficiency, specific fuel consumptions, Indicated thermal efficiency, brake thermal efficiency are set to be the parameters of performance of the engine. Engine performance is an indication of the degree of success with which it is doing its assigned job, i.e., the conversion of the chemical energy contained in the fuel into the useful mechanical work. The degree of success is compared on the basis of the following

- Specific fuel consumption, Brake mean effective pressure
- Indicated mean effective pressure, Indicated thermal efficiency
- Mechanical efficiency, Brake thermal efficiency

Table 1. B20 Blend Observations

S. No	Load on brake drum (W-S) kgf	Time for 10cc fuel consumption (Sec)	F.C. (Kg/hr)	Brake power (kW)	Indicated power (kW)	Specific fuel consumption (Kg/kW-hr)	Brake thermal efficiency (%)	Indicated thermal efficiency (%)	Mechanical efficiency (%)	I.M.E.P (bar)	B.M.E.P (bar)	F.M.E.P (bar)
1.	0	94	0.310	0	1.5	0	0	40.41	0	2.17	0	2.17
2.	1.8	73.2	0.399	0.5908	2.09	0.675	12.3	43.86	28.2	3.025	0.854	2.17
3.	3.6	58.76	0.497	1.1816	2.68	0.421	19.9	45.16	44.04	3.879	1.709	2.17
4.	5	51.26	0.570	1.6411	3.1411	0.347	24.11	46.15	52.24	4.54	2.37	2.17
5.	6.8	44.12	0.662	2.2319	3.7319	0.2968	28.22	41.5	68	4.748	3.22	2.17
6.	8	37.38	0.782	2.6257	4.12	0.2879	28.1	44.2	63	5.96	3.79	2.17

5.2 Results

1. Comparison of mechanical efficiency

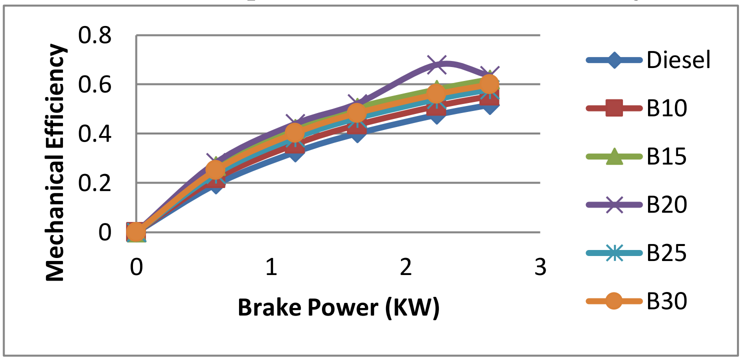

Fig 4: Brake Power Vs Mechanical Efficiency

From the Fig 4 it was observed that B20 blend offers the best Mechanical Efficiency among all the mixtures and therefore seems to be the best mixture with regards to the minimum Frictional Power. Diesel gives the least Mechanical Efficiency.

2. Comparison of Brake thermal efficiency

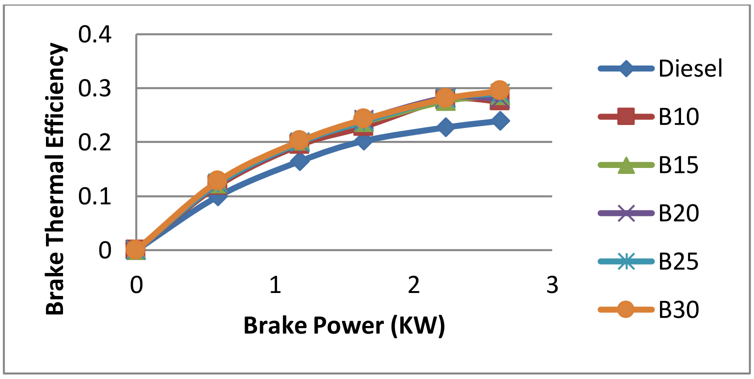

Fig 5: Brake Power Vs Brake Thermal Efficiency

From the Fig 5 it was observed that Diesel offers least Brake Thermal Efficiency and till 1KW B30 offers maximum Brake Thermal efficiency and in between 1KW to 3KW B20 offers maximum Brake Thermal efficiency.

3. Comparison of indicated thermal efficiency

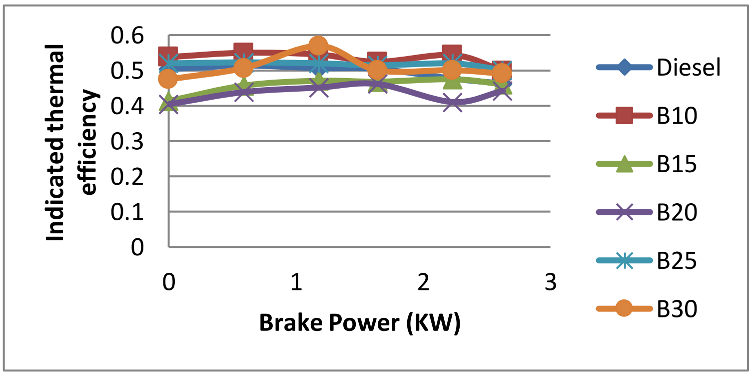

Fig 6: Brake Power Vs Indicated Thermal Efficiency

From the Fig 6 it was observed that B10 blend offers the maximum Indicated Thermal Efficiency of all the mixtures and it seems to be the best mixture, while B20 offers the minimum Indicated Thermal Efficiency.

4. Comparison of specific fuel consumption

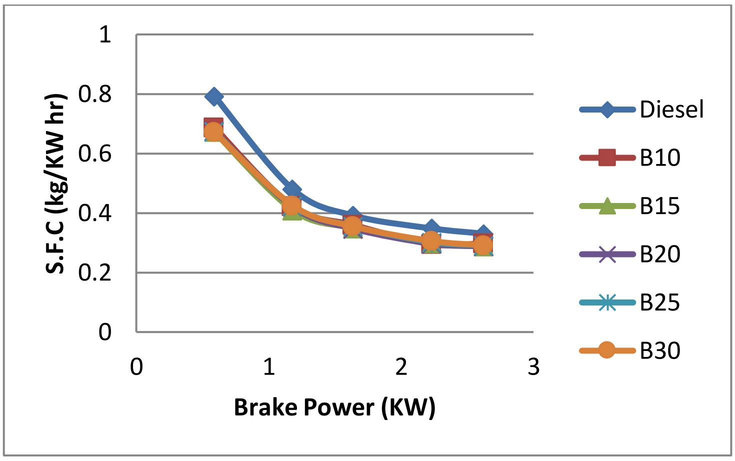

Fig 7: Brake Power Vs Specific Fuel Consumption

From the Fig 7 it was clear that , B15 blend offers the least Specific Fuel Consumption of all the mixtures while Diesel has the maximum Specific Fuel Consumption.

5. Comparison of indicated power

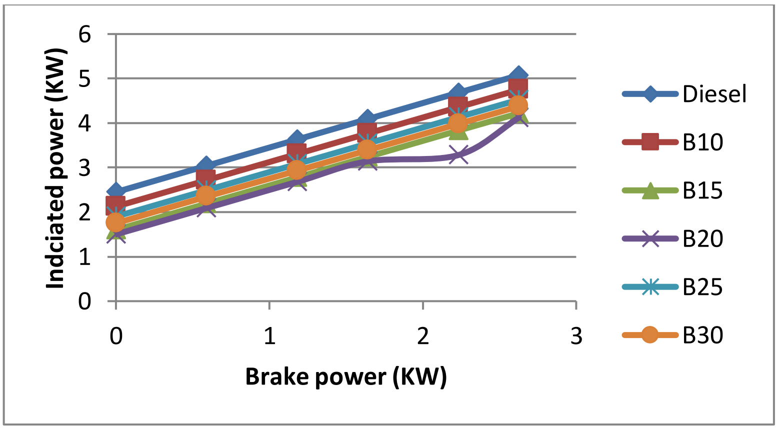

Fig 8: Brake power Vs Indicated Power

From the Fig 8 it was observed that B10 blend offers the maximum Indicated Power of all the mixtures and while B20 offers the minimum Indicated Power.

6. **Comparison of indicated mean effective pressure**

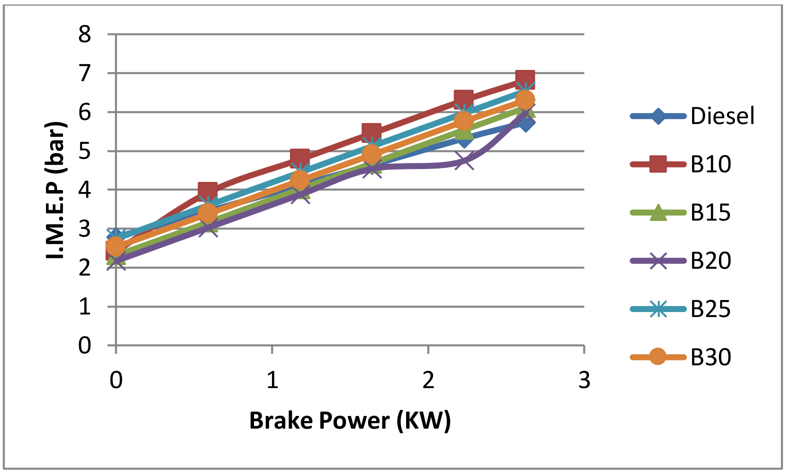

Fig 9: Brake Power Vs Indicated Mean Effective Pressure

From the Fig 9 it was observed that B20 blend offers the minimum Indicated Mean Effective Pressure of all the mixtures and it seems to be the best mixture with regards to minimum Frictional Power while B10 offers the maximum Indicated Mean Effective Pressure.

7. **Comparison of frictional mean effective pressure(F.M.E.P)**

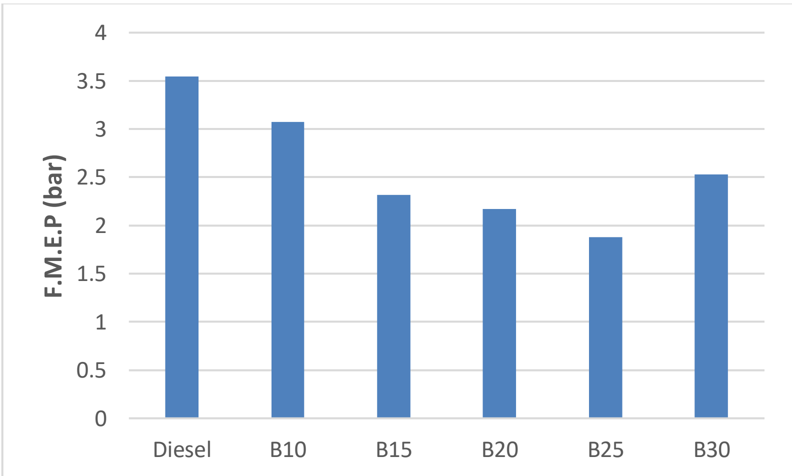

Fig 10: Blends Vs F.M.E.P.

The Fig 10 shows the graph for Frictional Mean Effective Pressure (F.M.E.P) for the various fuel blends and diesel. The maximum FMEP is obtained for the B10 fuel blend while B25 fuel has the minimum FMEP comparatively.

5.3 Discussions

In the above experiment, even for small loads frictional losses are more and decreases with the increase in biodiesel concentration and again decreases may be some inertia forces as result FMEP also follows same pattern. But SFC decreases as the blending percentage increases due to high viscosity of biodiesel whereas maximum mechanical efficiency of 68% occurs at 6.8 kgf load for B20 blend which may be the ideal condition for engine operation. BMEP and B.P is same throughout all blends due to same force application in stages.

6 Conclusions

The load test on the four stroke diesel engine has given good outputs for biodiesel from rubber seed oil because mechanical efficiency is maximum for biodiesel blend B20 and all other blends also has reasonable good efficiency due to less frictional losses. Other parameters like specific fuel consumption (spfc) is also less for biodiesel blends as the biodiesel percent increases, i.e due to increase in viscosity of the blend so the engine takes more time to compress the fluid. Moreover, due to no sulpur content in the produced biodiesel. The emissions may also decrease than the normal diesel. Due to high viscosities, engine strain and knocking characteristics may increase which reduces the life of engine and overall cost of production of biodiesel is also more. But with good maintenance and slight design modification in the existing engines can prolong the life of it and if it is produced on a large scale then the overall cost may comedown than the existing oils. From our experiments, usage of B20 blend oil gives the best performance characteristics for an engine with high efficiencies.

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