International Journal of Current Engineering and Technology
ISSN 2277 – 4106

Available at http://inpressco.com/category/ijcet

Research Article

Performance Evaluation of a Diesel Engine with Sesame Oil Biodiesel and its Blends with Diesel

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Abstract

The interest on alternative fuels is continuously increasing to meet the growing energy needs and protect the environment. A successful alternative fuel fulfills the environmental and energy security needs without sacrificing operating performance. One of the successful alternative fuels is biodiesel which is gaining attention in the present day world. Operationally, biodiesel blends perform very similar to conventional diesel in terms of performance and emissions without major modifications of engine because the properties of biodiesel and conventional diesel are similar. In this present work, biodiesel is prepared from sesame oil and short term tests were conducted with different blends of biodiesel and diesel on a single cylinder four stroke diesel engine and performance and emissions are evaluated and compared with diesel operation.

Keywords: *Sesame oil, biodiesel, esterification, performance parameters, emissions*

1. Introduction

The depletion of fossil fuels and their effects on environmental pollution necessitate the usage of alternative renewable energy sources in recent years. In this context, biodiesel is an important one of the alternative renewable energy sources which has been mostly used nowadays. Biodiesel is a renewable and energy-efficient fuel that is non-toxic, biodegradable in water and has lesser exhaust emissions. It can also reduce greenhouse gas effect and does not contribute to global warming due to lesser emissions because it does not contain much pollutants and its sulphur content is also lower than the mineral diesel. Biodiesel can be used, stored safely and easily as a fuel besides its environmental benefits. Also it is cheaper than the fossil fuels which affect the environment in a negative way. It requires no engine fuel system modification to run biodiesel on conventional diesel engines.

The main reason for high viscosity in raw vegetable oils is free fatty acids. Most popular method called trans-esterification is used to produce biodiesel which is a chemical reaction between vegetable oil and alcohol in the presence of catalyst to yield fatty acid alkyl esters and glycerol. Research is going on to prove the suitability of vegetable oil and their biodiesels as fuels of diesel engines. It was proved from the investigations that properties of bio diesel are similar to petro-diesel and requires little or no engine modifications. Investigations on preparation of bio diesels were carried out by numerous researchers and (Janahiraman et.al.,Chao-Chin Lai et.al., N. Akhavan Moghaddam et.al., G.S.Dodos et.al) reports have shown that physical properties of biodiesels prepared from rice bran oil, jatropha oil, waste frying oil and sesame oil etc. are very close to properties of petro-diesel and can be recommended as fuel for use in diesel engine. Investigations were also carried to check suitability of biodiesel prepared from palm oil (Praveen K. S. Yadav et.al., Praveen K. S. Yadav et.al.) and successful results were reported. Experiments were conducted with Neem oil biodiesel (Sivanathan Sivalakshmi, Elango T) and improvements in performance, peak cylinder pressure, reduction in emissions were reported. Biodiesel is also prepared with used cooking oil (G Lakshmi Narayana Rao et.al.) and it was observed that even though thermal efficiency was slightly reduced, emissions were significantly reduced promising the replacement of petro-diesel with bio diesel. Bio diesel can also be blended with ethanol (G. Venkata Subbaiah et.al) to reduce the emissions as well as usage of petro-diesel. Bio diesels beef tallow, canola oil, Soya bean oil and yellow grease (Robert L. McCormick) were tested in heavy duty engines and reduction in particulate matter and increase in NOx emissions were observed.

2. Engine Data

2. 1 Engine Specifications

Make : Kirloskar

***Shailaja.M**, **A. Aruna Kumari** are working as Asst. Prof. and **A V Sita Rama Raju** is working as Prof.

BHP : 5 hp
Bore : 80 mm
Stroke : 110 mm
Speed : 1500 RPM
Method of cooling : Water Cooled
Air Drum Orifice : 20 mm
Type of ignition : Compression Ignition
Method of loading : Electric dynamometer.
Maximum Load : 12.5 Amp

Fig.1. Photograph of engine used for experimentation.

2.2 Exhaust gas analyser specifications

Make : Indus Scientific Pvt.Ltd.

Table.1. Specifications of Exhaust Gas Analyse

Exhaust gas	Measurement	Resolution	Accuracy
CO	0-15.0% vol	0.01% vol	± 0.06%
CO_2	0-20.0% vol	0.01% vol	± 0.5% vol
HC	0-30000 PPM	1 ppm vol	± 12PPM
O_2	0-25.0% vol	0.01% vol	± 0.1% vol
NO_X	0-5000 PPM	1 ppm vol	± 50% vol

3. Experimentation

The present section is discussed in two segments namely preparation of bio diesel and performance and emission test of biodiesel.

3.1 Preparation Of Biodiesel

Biodiesel is commonly produced by the transesterification of the vegetable oil or animal fat feed stock. Though there are several processes for transesterification, batch reaction process is adopted due to the simplicity and adoptability in the laboratory. The percentage of free fatty acids present in the sample of the fuel is estimated by titration process, and the amount of KOH and Methanol is calculated. Following are the sequence of processes in the preparation of biodiesel.
Step 1: Estimation of free fatty acid.
Step 2: Calculation of mass of KOH required for the solution.
Step 3: Calculation of mass of methanol required for the reaction.
Step 4: Calculation of volume of methanol required per liter of sesame oil.
Step 5: Calculation of weight of KOH required per liter of sesame oil.
Step 6: Preparation of biodiesel.

3.1.1 Estimation of free fatty acid % in the oil

In order to estimate the percentage of free fatty acid in the sample of vegetable oil, it is titrated.
AV = {(A-B) x N x 56.1} ÷W
Where
A = number of ml of KOH to neutralize sample beaker
B= number of ml of KOH to neutralize blank beaker
N = normality of KOH solution (0.1 in this case)
W = weight of sample in grams
%FFA ≈ ´ (AV)

3.1.2. Calculation of the mass of koh required for the titration

When the FFA level is less than 1%, and certainly if it is less than 0.5%, the FFAs can be ignored .Common catalyst amounts are:

Sodium hydroxide : 1% of triglyceride weight
Potassium hydroxide : 1% of triglyceride weight
Sodium meth oxide : 0.25% of triglycerides weight

When FFA levels are above 1%, it is possible to add extra alkali catalyst. This allows a portion of the catalyst to be devoted to neutralizing the FFAs by forming soap, while still leaving enough to act as the reaction catalyst. Since it takes one mole of catalyst to neutralize one mole of FFA, the amounts of additional catalyst can be calculated by the following formulae:

Sodium hydroxide [%FFA] (0.144) + 1 %
Potassium hydroxide [%FFA] (0.197)/0.86 + 1 %
Sodium meth oxide [%FFA] (0.190) + 0.25 %

For transesterification process alcohol to triglyceride (sample oil) ratios from 4:1 to 20:1 (mole: mole) were taken.

3.1.3. Calculations to determine ffa % and the mass of koh required for the titration

Number of ml of KOH to neutralize sample beaker (A) = 0.4 ml

Number of ml of KOH to neutralize blank beaker (B) = 0.2 ml
Molarity of KOH solution (M) = 0.1
Weight of sample in grams (W) =0.9
AV= {(0.4-0.2)×0.1×56.1}÷0.9=1.23
%FFA = ½ (1.23) = 0.615
Therefore percentage of free fatty acids in the sample oil is 0.615.
As the FFA % is less than 1, the FFAs can be ignored and required amount of catalyst (KOH) is 1% of triglyceride weight (oil sample).

3.1.4. Calculation of the mass of methanol required for the reaction

Molecular weight of fatty acids in sesame oil sample
Oleic acid : 282.465(42.25%)
Stearic acid : 284.481(4.75%)
Palmitic acid : 256.428(9.5%)
Linoleic acid : 280.450(42.25%)
Linolenic acid : 278.434(0.5%)
Palmitioleic acid : 254.408(0.25%)
Eicosenoic acid : 310 .51(0.5%)

The molecular weight of Fatty acids in sesame oil sample =(282.465×0.4225)+(284.481×0.0475)+(256.428×0.095)+(280.45×0.4225)+(278.434×0.0005)+ (254.408×0.0025) +(310.51×0.0005)
=279.28 gm
Therefore the molecular weight of Fatty acids in sesame oil sample is = 279.28 gm.
Molecular weight of triglycerols of sesame oil =(173.10)+(3×279.28) =1011 gm.
Selecting a mole ratio of 6:1 the weight of methanol required per 1011 gm of sesame oil as
6×32.04= 192.24 gm

3.1.5. Volume of methanol required per liter of sesame oil

Volume of 192.24 gm of methanol =192.24÷0.8 =240.3 ml
Volume of 1011 gm of sesame oil =1011÷0.91=1111 ml
Hence volume of methanol required per liter of oil = 216 ml

3.1.6. Method of preparation

1.5 liters of sesame oil is taken in a 2 liter beaker and it is heated on a water bath (approximately to 40^0 C), to get cloudless clear oil.
13.65 gm of KOH is mixed with 324 ml of methanol and stirred until KOH dissolves completely.
Mixture of KOH and methanol is added to 1.5 liters of sesame oil at 40^0C and the contents are transferred in to a 2 liter bottle and shaken rigorously for 10 minutes to ensure proper mixing of oil, alcohol and catalyst. The bottle is kept upside down without any movement for 2-days and it is observed the formation and settlement of glycerin at the bottom and biodiesel at the top.
Glycerin is collected carefully and left over biodiesel is washed with water and dried in sun to remove any water present.
The yield of biodiesel is found to be 1450 ml.

3.2. Performance and emission test on engine

The following experiments were carried out on 4 stroke single cylinder diesel engine.

- Varying load performance tests conducted using diesel as fuel.
- Varying load performance tests conducted using sesame oil biodiesel as fuel.
- Varying load performance tests conducted using 5 different blends of sesame oil biodiesel and diesel as fuel.

Following are the percentages of sesame oil biodiesel & diesel in blends.
10% sesame oil biodiesel + 90% Diesel
20% sesame oil biodiesel + 80% Diesel
25% sesame oil biodiesel + 75% Diesel
30% sesame oil biodiesel + 70% Diesel
40% sesame oil biodiesel + 60% Diesel
Over entire range of engine operation, performance tests were conducted at 6 different load settings.
With each of the above mentioned fuels, engine was run approximately for one and half hour duration and 15 minutes at each load setting. For accuracy each observation is taken thrice and averaged.

Brake power, indicated power, total fuel consumption, specific fuel consumption, actual volume, swept volume, brake thermal efficiency, indicated thermal efficiency, volumetric efficiency and mechanical efficiency were calculated using observations noted.
Friction power was estimated by Willan's line method.

4. Results and discussions

After conducting the experiments various performance parameters were calculated and plotted in the form of the graphs.

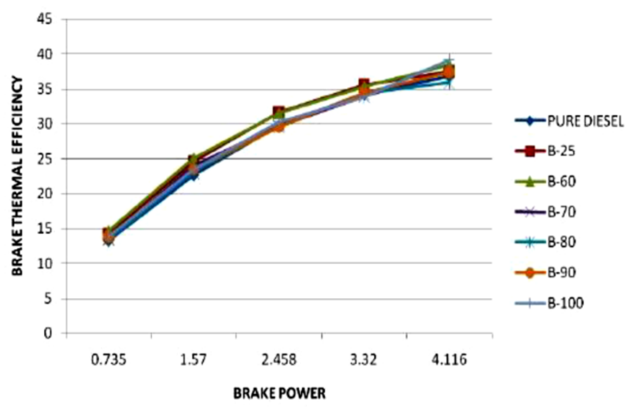

Fig.3. Brake power Vs Brake Thermal Efficiency

Fig. 3 – Fig.11 indicate the variation of various performance and emission parameters with respect to load or brake power. It is observed from the figures that brake

thermal efficiency and mechanical efficiency increase with increase in load, B25 and B60 give maximum brake thermal efficiency and mechanical efficiency respectively. Highest indicated thermal efficiency is obtained for B100

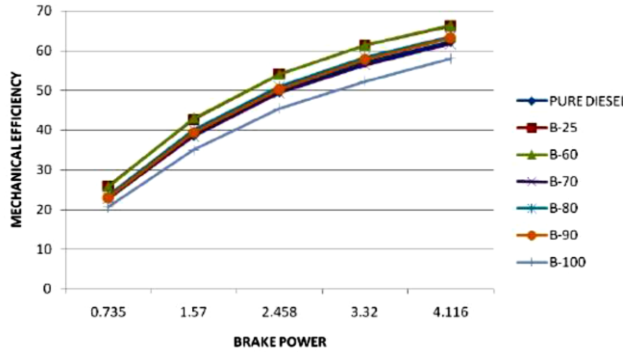

Fig.4. Brake power Vs Mechanical Efficiency

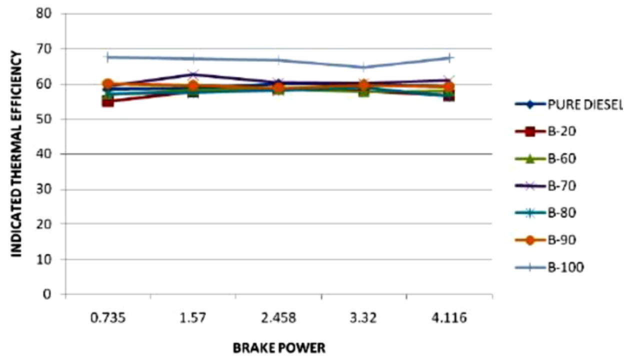

Fig.5. Brake power Vs Indicated Thermal Efficiency

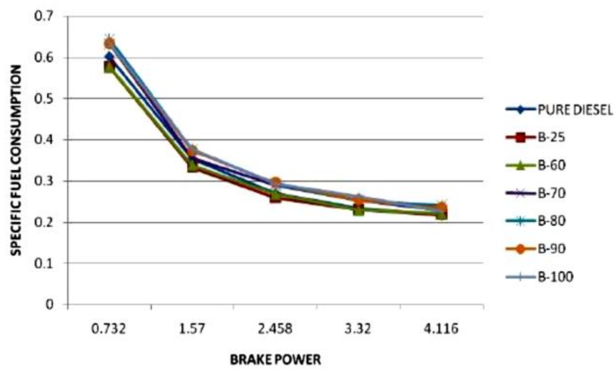

Fig.6. Brake power Vs Specific Fuel Consumption

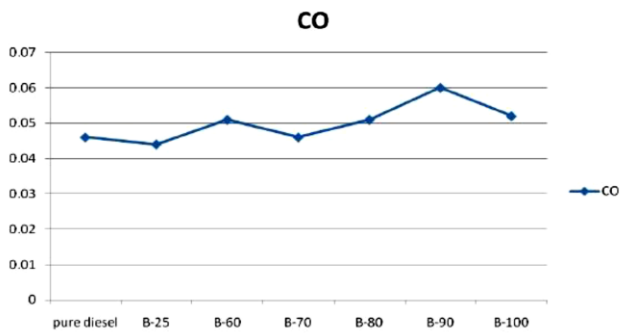

Fig.7.Type of fuel Vs CO

and lowest bsfc for B 25. Engine load or brake power has much less effect on emissions and hence type of fuel was taken as variable and graphs have been drawn. Emissions with biodiesel operation were less compared to diesel operation. The reasons for all above may be presence of oxygen in the biodiesel which leads to better combustion and fewer emissions.

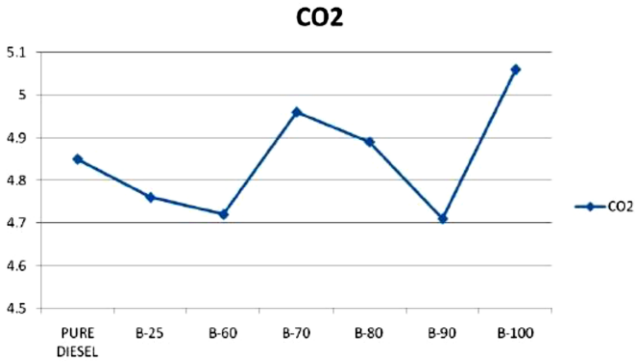

Fig.8.Type of fuel Vs CO_2

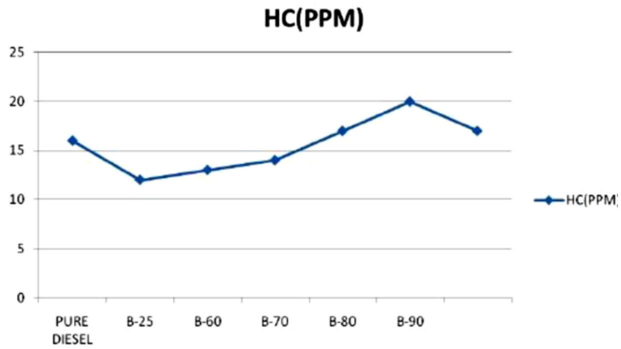

Fig.9.Type of fuel Vs HC

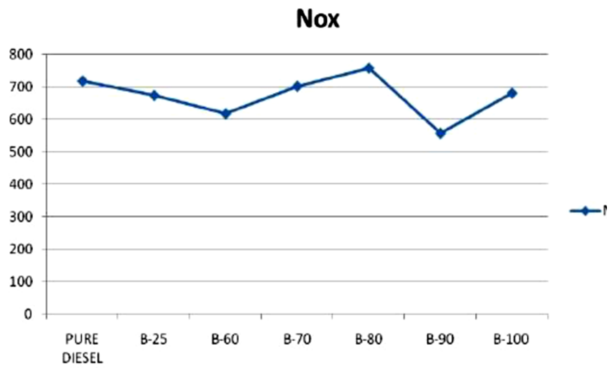

Fig.10.Type of fuel Vs NO_x

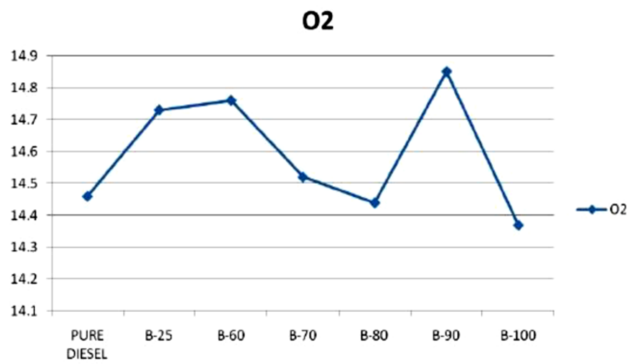

Fig.11.Type of fuel Vs O_2

Conclusions

From results of experiments following conclusions may be drawn.

- Sesame oil bio diesel is proved potentially suitable as fuel for a diesel engine.
- Performance and emissions are better with sesame biodiesel operation compared to diesel operation.
- As no engine modifications are required sesame biodiesel may be directly used in any diesel engine.
- Only short term tests were conducted, long term tests may reveal clearer picture of engine operation and life.
- Recommendations may be made to produce sesame oil not only for edible and medicinal purposes but for also for fuel by creating awareness among farmers.

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