Performance Evaluation of a Diesel Engine Fuelled with Blends of Hybrid Biodiesel

[#1]Mr.Dipak S. Sanap, [#2]Prof.N.C.Ghuge

Mechanical Engg. department, University of Pune, Matoshri college of Engineering and Research Centre, Eklahare, Nashik, Maharashtra, India.
Mechanical Engg. department, University of Pune, Matoshri college of Engineering and Research Centre, Eklahare, Nashik, Maharashtra, India.

Abstract: In the quest for renewable energy resource, efforts are made to find out options to alternative fuels. Biomass derived vegetable oils are very suitable alternative fuels for diesel engine. Blending of different vegetable based fuels becomes a necessity and is gaining the attention of many researchers because the properties of biodiesel prepared from vegetable oils are very close to that of diesel. In this work, the performance of diesel engine is evaluated using Hybrid biodiesel i.e. mixture of Cotton seed and Eucalypus i.e. Nilgiri oil biodiesel in equal proportion as fuel. Different blends of both oils are prepared and performance and emission characteristics of C.I. engine is determined. Comparative performance study gives the best blend for the diesel engine. The results shows that engine performance when fuelled with the biodiesel are comparable to that when fuelled with petroleum diesel. B37 is found to be the best blend as it has highest Brake power and volumetric efficiency as well as higher brake thermal efficiency and less emissions as compared to the other blends.

Keywords: Engine performance; Emission; Cotton seed and Eucalyptus hybrid biodiesel.

1. INTRODUCTION

The world is currently facing a major energy crisis. Many countries dependent on fossil fuels as their main source of electricity and transportation. As fossil fuels are depleting its price is increasing day by day. Thus it becomes necessary to find a solution to this growing crisis by finding a renewable, easily available and economically attainable source of renewable energy. Biodiesel can satisfy both these criteria's of sustainability and economic feasibility. Biodiesel being renewable, biodegradable fuel can minimize our dependence on conventional fossil fuels and also contribute in improving environmental quality in metro cities, urban and rural sectors by reducing obnoxious automotive/vehicular emissions. Biodiesel being easily available, clean source of energy has the ability to replace diesel as an alternative in near future.

Compression ignition (C.I.) engines are the most fuel-efficient engines due to their relatively high compression ratio and few throttling losses. C.I. engines have comparatively less emissions of carbon monoxide and unburned hydrocarbon than other engines. Biodiesel is made entirely from vegetable sources which does not contain any sulfur, metals, crude oil residues or aromatic hydrocarbons. Biodiesel is an oxygenated fuel. Emissions of carbon monoxide and soot particles reduces when compared to conventional diesel fuel. Due to the use of biodiesel global warming is avoided as CO_2 emitted is again absorbed by the plants grown for vegetable oil/biodiesel production. Thus CO_2 balance is maintained. Biodiesel could be produced from wide variety of vegetable oils such as palm oil, sunflower oil, neem oil, coconut oil, soyabean oil, Rice bran oil, Jatropha, pongamia etc. But most of these are edible oils. The non-edible oils are Nerium, Cotton seed and Eucalyptus i.e. nilgiri oil etc.

In the present work biodiesel is produced from two different sources of non-edible vegetable oils namely Cotton seed oil and Nilgiri oils. These both oils are mixed with each other in equal proportion by transesterification process and different blends of hybrid biodiesel is prepared. The performance and exhaust emissions of diesel engine using blends of Cotton seed and Eucalyptus i.e. Nilgiri oil biodiesel as fuel is evaluated.

Rakopoulos et al. studied to evaluate and compared the use of a wide variety of vegetables oils or biodiesels of various origins containing cottonseed as substitute to conventional diesel fuel at blend ratios of 10/90 and 20/80 in a direct injection diesel engine. Results showed that the smoke density was significantly reduced with the use of biodiesel blends as compared to that of the neat diesel fuel, the emissions were slightly decreased with the use of biodiesel blends.

Peterson CL et al. suggested that the transesterification process has been proven worldwide as an effective means of biodiesel production and reduction in viscosity of vegetable oil. Temperatures, catalyst type, concentration ratio of alcohol to fuel and stirring speed rate have been observed to influence the transesterification process to a greater extent.

Geyer et al. reported on cottonseed oil methyl ester as a fuel in a direct injected diesel engine and concluded that the thermal efficiency was increased , smoke opacity was reduced and NOX emissions was increased.

Llkilic et al. studied the effects of cotton seed oil methyl esters on engine performance in a single cylinder diesel engine. There was little or no significant difference between the torque and power output of CSOME and diesel fuel usage especially at medium and higher speeds.

M. Leenus et al. worked on finding the feasibility of cotton seed oil as a fuel for the diesel engines by comparing the various methods to improve the performance of cotton seed oil. The brake thermal efficiency of diesel and CSO at is 32.3% and 28% respectively. Brake thermal efficiency is increased up to 30.4% with ethyl ester of cotton seed oil (EECSO). Smoke, HC and CO levels are minimized with EECSO compared to CSO. A blend of 60% CSO and 40% of diesel results in better brake thermal efficiency and a considerable diminution in smoke level. It is accomplished that CSO and EECSO can be used directly in diesel engines without any modification.

Tarabet et al. studied on the examination of using eucalyptus biodiesel as fuel in diesel engine. A diesel engine was used to experiment eucalyptus biodiesel and its blends with diesel fuel in different ratios at more than a few engine loads. Performance and exhaust emissions are evaluated for different operating conditions. From the result it is cleared that neat eucalyptus biodiesel and its blends cause important reduction in exhaust emissions mainly at high loads when compared to those of diesel fuel.

Md. Nurun et al. worked on the performance test of a diesel engine with neat diesel fuel and biodiesel mixtures. Biodiesel was prepared by transesterification process. Cottonseed oil (CSO) was preferred for biodiesel production. Cottonseed is non-edible oil, thus food versus fuel difference will not come up if this is used for biodiesel production. A maximum of 77% biodiesel was formed with 20% methanol in attendance of 0.5% sodium hydroxide. The engine investigational results showed that exhaust emissions counting particulate matter (PM), carbon monoxide (CO), and smoke emissions were reduced for all biodiesel mixtures.

Poola et al. in his study, adopted the direct use and blending. Biomass derived Eucalyptus oil is selected and directly blending with the diesel fuel without any changes to the oil. Eucalyptus oil is extracted from the foliage of the eucalyptus tree. Eucalyptus oil has a sharp, fresh, clear and very distinctive smell. And it is pale yellow in color and watery in viscosity. Eucalyptus oil making is possible throughout the year as the eucalyptus leaves are accessible abundantly throughout the year. From the results, it is noted that Orange oil and Eucalyptus oil can be the potential contender for the internal combustion engines.

R. Senthil Kumar et al. carried out performance test on horizontal single cylinder changeable speed Greaves engine with different blends of cottonseed oil (B5, B10, B15, B20, B40 & B100) and compare the presentation of cottonseed oil with diesel. Blending usual Diesel Fuel (DF) with esters (usually methyl esters) of vegetable oils is currently the most common form of biodiesel. The most common ratio is 80% usual diesel fuel and 20% vegetable oil ester indicating the 20% level of biodiesel and represented as B20. The TFC and SFC of B20 residue found to be very stable on different loading conditions and B15 and B20 blends has a moderate NOx and CO emission. B20 diesel with blend 20% yields the best possible value, with less fuel consumption.

N. S. Senthur et al. suggested the suitability of Eucalyptus biodiesel as another engine fuel for utilization in Compression Ignition Engines. In this experimental analysis, biodiesel was created from pure eucalyptus oil by the process of transesterification. The prepared biodiesel was then blended with diesel in three proportions (10%, 20% and 30% by vol.) and then test was taken on a single cylinder direct injection diesel engine to evaluate the performance and emission parameters. The BSFC increases with increase of biodiesel content in the fuel blend due to decline in calorific value of the blend. The Brake Thermal Efficiency of biodiesel blends are found to be somewhat lesser than that of diesel at all loads and power outputs of the engine mostly due to the reduced heating value of the blend.

From the review of literatures, numerous works is done on the utilization of biodiesel as well as its blends in engines. Many of the literatures focused on single biodiesel and its blends. From above studies, it is clear that single biodiesel offers acceptable engine performance and emissions for diesel engine operation. The engine performance using the biodiesel and vegetable oil blends of various origins was found to be similar to that of neat diesel fuel.

Very few experiments have been conducted with the combination of dual biodiesel i.e. Hybrid biodiesel and diesel as a fuel. Most of the literatures suggested that Eucalyptus i.e. Nilgiri oil and Cotton seed is a suitable substitute of diesel. So, the combination of Eucalyptus oil and Cotton seed oil for this current study which is easily and locally available is selected.

The objectives of this work are as follws:

i) To obtain homogeneous mixture and prepare a hybrid biodiesel of 2 non edible oils i.e. cotton seed and Eucalyptus i.e. nilgiri oil.

ii) To determine the fuel properties like Density, Calorific value, Viscosity, Cetane number, Flash point and carbon residue of the hybrid biodiesel blends.

iii) Evaluation of performance characteristics like specific fuel consumption, compression ratio, thermal efficiency of a diesel engine fuelled with blends of hybrid (cotton seed and nilgiri oil) biodiesel.

iv) To evaluate exhaust gas emissions from diesel blended hybrid (cotton seed and nilgiri oil) biodiesel.

v) To suggest best blend of hybrid biodiesel for diesel engine.

2. Biodiesel blends

Transesterification reaction:

The main components of animal fats and vegetable oils are Triglycerides. The vegetable oil or animal fat is subjected to a chemical reaction called Transesterification to produce biodiesel. The fatty acid triglycerides are esters of fatty acids and the chemical divides up of the heavy molecules and forming simpler esters is termed as Transesterification. These triglycerides are reacted with a alcohol (Methyl, Ethyl, or others) in the presence of a catalyst under a restricted temperature for a given length of time. The final products are Alkyl esters and Glycerin. The Alkyl esters are having positive properties as fuels for use in CI engines, are the main product and the Glycerin, is a by-product

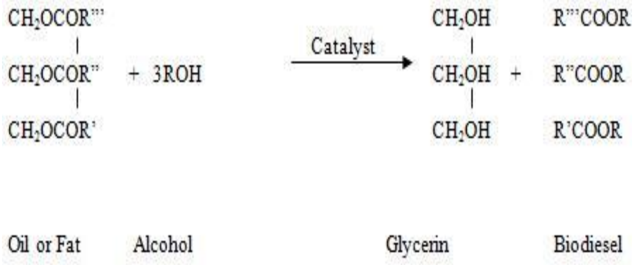

Fig. 01 Transesterification reaction

1. Filtering: The vegetable oil is first filtered to remove solid particles from it. It is to be warmed up a bit first to get it to run freely; 35°C should be enough. A Cartridge filter is used for the same.

2. Removing the Water: First the oil is heated to remove the water content. vegetable oil may contain water, which can slow down the reaction and causes saponification (soap formation). Then the temperature is raised to 100°C, holding it and allow water contents to boil off. Run the agitator to avoid steam pockets forming below the oil and exploding, splashing hot oil puddles out from the bottom. When boiling slows, the temperature is raised to 130°C for 10 minutes and allow cool to it.

Fig. 02 Transesterification set up

With the help of transesterification process various blends of biodiesel are prepared. The biodiesel blended with diesel by volume as B20 (20% Hybrid biodiesel i.e. 10% Cotton seed and 10% Eucalyptus biodiesel and 80% diesel fuel), B37(37% Hybrid biodiesel i.e. 18.5% Cotton seed and 18.5% Eucalyptus biodiesel and 63% diesel fuel), B43 (43% Hybrid biodiesel i.e. 21.5% Cotton seed and 21.5% Eucalyptus biodiesel and 57% diesel fuel), B100 (100% Hybrid biodiesel i.e. 50% Cotton seed and 50% Eucalyptus biodiesel). Then the samples were proceed for their property testing.

Fig. 03 Blends of Hybrid biodiesel

The physico-chemical properties of Hybrid biodiesel i.e. Equal mixture of cotton-seed and Eucalyptus oil biodiesel is given in the Table 1. The density, Calorific value, Cetane no., Viscosity, Flash point, carbon residue and moisture content are comparable with that of diesel fuel.

Hybrid Bio-diesel blends	Density (gm/cc)	Calorific Value (MJ/Kg)	Cetane no.	Viscosity (mm2/sec)	Flash Point (0C)	Carbon residue (%)
B00 (Pure Diesel)	0.830	42.5	49.00	2.78	64	0.5
B20	0.840	41.98	-	-	-	-
B37	0.842	41.59	-	-	-	0.467
B43	0.846	41.25	-	-	-	-
B100	0.872	39.50	51.35	5.2	142	0.400

Table 1 Tested Properties of Hybrid Biodiesel

3. Experimental Set up

Sr. No	Description	Specifications
1.	Make	Kirloskar TV1 Engine
2	No. of Cylinders	1
3	No. of strokes	4
4	Cylinder diameter	87.5 mm
5	Stroke length	110 mm
6	Connecting rod length	234 mm
7	Orifice diameter	20 mm
8	Dynamometer arm length	185 mm
9	Fuel	Diesel
10	Power	3.5 kW
11	Speed	1500 rpm
12	CR range	12:1 To 18:1
13	Injection point	0 to 25 C
14	Software	IC Engine soft

Table 2 Test Engine specifications

Fig. 04 Experimental Set up

The engine was started and allowed to run for 15-20 minutes to get stabilized using pure diesel fueland baseline data for B00 was generated. Compression ratio was set at 16:1 and performance parameters were noted using I.C. engine software. The exhaust gas emission parameters like HC, NOx, CO2, CO were recorded by pelting the probe of AVL gas analyzer in the exhaust pipe. For noting the value of smoke (opacity) the exhaust gas was directed to AVL smoke meter and the opacity was recorded. Then the load on the engine was furher increased from 0 kg to 3 kg, 6 kg, 9 kg and 12 kg while keeping the fuel injector triggering pressure and fuel injection advance angle unchanged. The engine was run for sufficient time duration to ensure that the diesel fuel phase is over and the engine has started running with Hybrid biodiesel as fuel. The entire process was repeated while engine running with different blendsof hybrid biodiesel i.e. B20, B37, B43 and B100 as a fuel and various performance and emission parameters were noted.

4. Equations

Brake power (B.P) = 2πNT/60000(kW)

Specific fuel consumption (SFC) = 10-ml/sec

Volumetric efficiency (ηvol.) = actual air flow/theoretical airflow*100(%)

5. Results and discussion

5.1 Engine performance Analysis- The engine performance parameters such as BP, SFC, Brake Thermal Efficiency, and Volumetric Efficiency obtained with HB00, HB2, HB37, and HB43 and HB100 are discussed in the following sections.

Fig. 04 Experimental Set up

The engine was started and allowed to run for 15-20 minutes to get stabilized using pure diesel fuel and baseline data for B00 was generated. Compression ratio was set at 16:1 and performance parameters were noted using I.C. engine software. The exhaust gas emission parameters like HC, NOx, CO2, CO were recorded by pelting the probe of AVL gas analyzer in the exhaust pipe. For noting the value of smoke (opacity) the exhaust gas was directed to AVL smoke meter and the opacity was recorded.

Then the load on the engine was furher increased from 0 kg to 3 kg, 6 kg, 9 kg and 12 kg while keeping

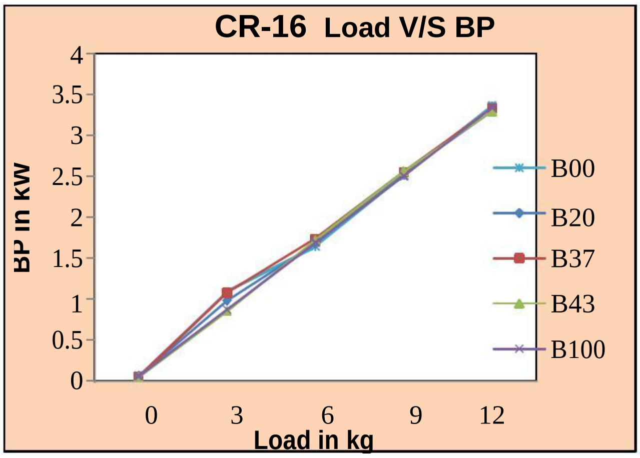

Fig. 05 Load vs Brake Power

It can be said from above graph, the Brake Power of B37 is increased by 1.16% as compared to pure diesel (B00).

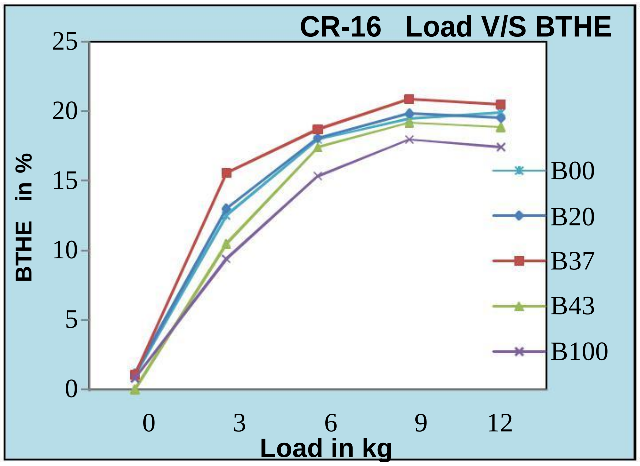

Fig. 06 Load vs BTHE

It can be said from above graph, the Brake Thermal Efficiency of B37 increased by 8.16% and B20 is improved by 0.97% as compared to pure diesel (B00).

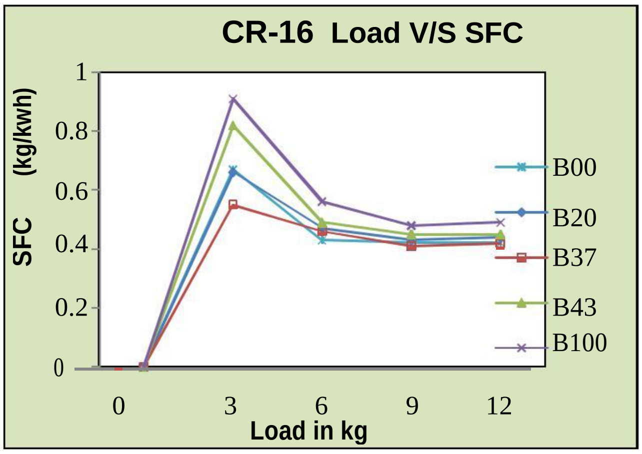

Fig. 07 Load vs SFC

It is observed from above graph, the SFC of B37 is 5.15% less as compared to pure diesel (B00).

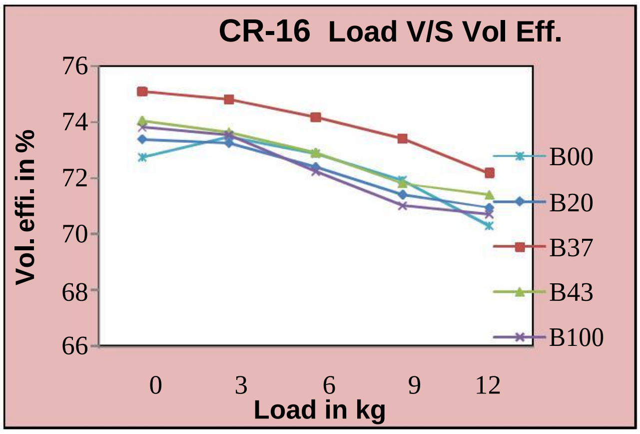

Fig. 08 Load vs volumetric efficiency

It can be said from above graph, the volumetric efficiency of B37 increased by 2.32% and B43 is increased by 0.69% as compared to pure diesel (B00).

5.2 Exhaust Emissions Performance Analysis-

The performance parameters such as CO, CO_2, HC (ppm), Nox, O_2 obtained with B00, B20, B37, and B43 and B100 and are discussed in the following sections.

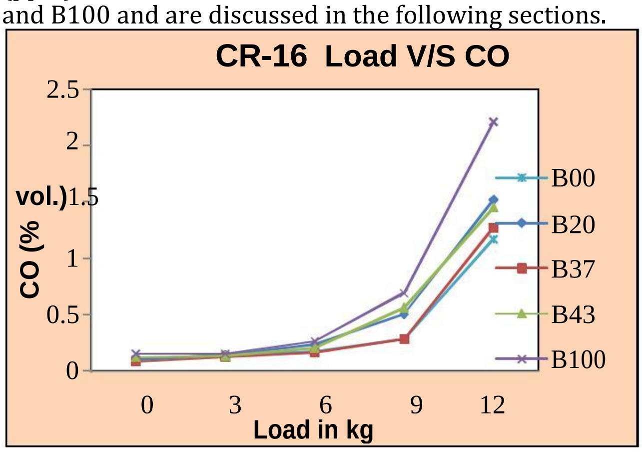

Fig. 09 Load vs Carbon Monoxide

For B20 and B43 CO emissions have increased by 33.87% and 32.26% respectively.

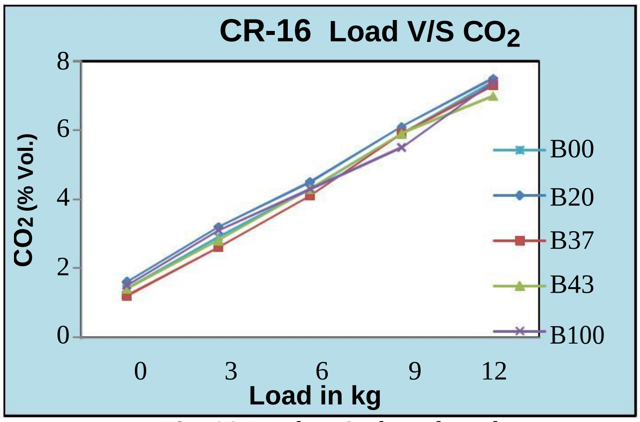

Fig. 10 Load vs Carbon dioxide

It can be said from above graph, the percentage of CO_2 emissions is decreased by 3.65% for B37 and reduced by 2.28% for B43 as compared to pure diesel (B00).

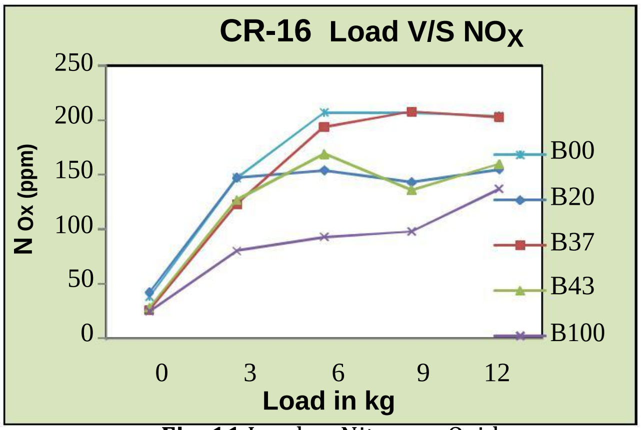

Fig. 11 Load vs Nitrogen Oxide

It is observed from above graph, the percentage of NO_X reduced by 46.07% for B100, reduced by 20.17% for B20, 22.78% for B43, 6.10% for B37 as compared to pure diesel (B00).

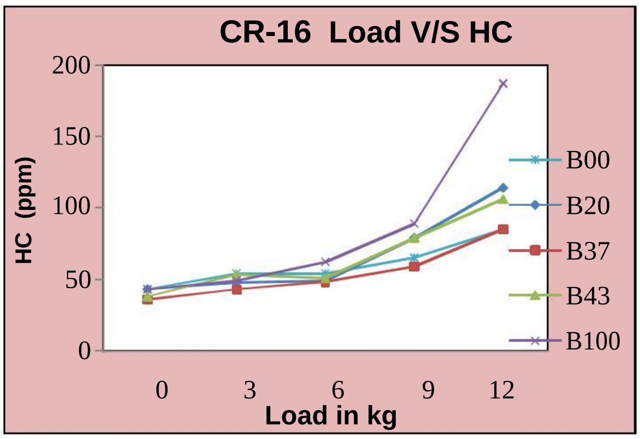

Fig. 12 Load vs HC

It can be said from above graph, The percentage of HC of B37 is reduced by 9.96%.

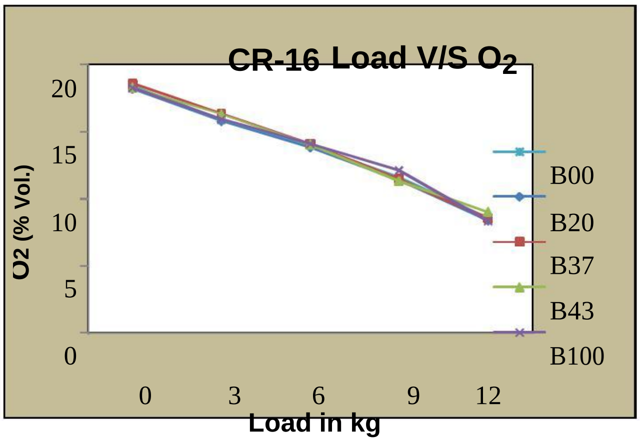

Fig. 13 Load vs Oxygen

It is observed from above graph, the O_2 percentage of B20 is 1.33% less than that of pure diesel (B00).

Conclusion

The Experimental work carried out in this study, and the conclusion made from above discussions are as follow

- The Brake Power of B37 is increased by 1.16% as compared to pure diesel (B00).
- The Brake Thermal Efficiency of B37 is increased by 8.16% and B20 is increased by 0.97% as compared to pure diesel (B00).
- The SFC of B37 is 5.15% reduced as compared to pure diesel (B00).
- The volumetric efficiency of B37 is increased by 2.32% while for B43 it is increased by 0.69% as compared to pure diesel (B00).
- The CO emissions of B100 is considerably increased. For B20 and B43, CO emissions have increased by 33.87% and 32.26% respectively and while for B37 CO emissions is nearly same as that of pure diesel (B00).
- The percentage of CO_2 emissions is decreased by 3.65% for B37, For B43 it is reduced by 2.28% and B100 it is nearly same compared with pure diesel (B00).
- The percentage of HC of B37 is reduced by 9.96% but for B100 HC emissions are considerably increased upto 42.85% as compared to pure diesel (B00).
- The O_2 percentage of B20 is 1.33% less than that of pure diesel (B00) while it is increased by 0.89% for B43.
- For Hybrid biodiesel blends NOx emissions have considerably reduced by 46.07% for B100, reduced by 20.17% for B20, reduced by 22.78% for B43 and for B37 it is reduced by 6.10% compared with pure diesel (B00).

From the results it can be concluded that B37 is found to be the best blend as it has highest Brake power and volumetric efficiency as well as higher brake thermal efficiency as compared to diesel and other blends. Emissions of HC, CO_2 and NOx is also reduced as compared to pure diesel.

References

Rakopoulos C.D, Antonpoulos K.A, Hountalas D.T, Giakoumis E.G, (2006),comparative performance and emission study of direct injection diesel engine using blends of diesel fuel with vegetable oils or biodiesel of various origins. *Energy conservation and management*; 47:32, pp.71-87.

Peterson CL, Reece DL, Hammond DL, Cruz R, Thompson JA, (1992), Comparison of ethyl and methyl esters of vegetable oils as diesel fuel substitute.

Proceeding of Alternate Energy Conference, ASAE pp.99-110.

Geyer SM, Jacobus MJ, Lestz, (1984), Comparison of diesel engine performance and emission from Neal and transesterfied vegetable oils *ASAE 1984;27(2):375-84.*

Likilic C Yucesu HS, (2002), The effect of cottonseed oil methyl ester diesel fuel blends on performance of diesel engine. Journal of Firat university natural and engineering sciences, 14(1): pp.199-205.

M. Leenus Jesu Martin, V Edwin Geo, D. Kingsly Jeba Singh, B. Nagalingam, (2012), A comparative analysis of different methods to improve the performance of cotton seed oil fuelled diesel engine. *Fuel 102) 372-378*

L. Tarabet, K. Loubar, M. S. Lounici, S. Hanchi, M. Tazerout, (2011), Experimental evaluation of performance and emissions of DI diesel engine fuelled with eucalyptus (nilgiri) biodiesel. *IMechE, London*Md. Nurun Nabi, Md. Mustafizur Rahman, Md. Shamim Akhter, (2009), Biodiesel from cotton seed oil and its effects on engine performance and exhaust emissions.

ATE 29 pp.2265 – 2270.

Poola R.B, Nagalingam B, Gopalakrishnan K.V, (1994), Performance studies with biomass-derived high-octane fuel additives in a two-stroke spark-ignition engine,

Biomass and Bioenergy pp. 369-379.

R. Senthil Kumar, R.Manimaran, (2013), Performance and emission characteristics on 4-stroke single cylinder C.I. engine using cotton seed bio fuels, *Asian Journal of Engineering Research/Vol. I/Issue II/Jan.-March.2013/01-03*

N. S. Senthur, T. S Ravikumar, Cijil. B. John, Eucalyptus Biodiesel, (2014), an Environmental friendly fuel for Compression Ignition Engines, American Journal of Engineering Research (AJER), Volume-03, Issue-03, pp-144-149.

] K. Anandavelu, N. Alagumurthi, and C.G. Saravannan, (2011), Experimental Investigation of Using Eucalyptus Oil and Diesel Fuel Blends in Kirloskar TV1 Direct Injection Diesel Engine, *Journal of Sustainable Energy and Environment pp.97.*

Vaneet Bhardwaj, Varun Singla, Pradeep Gaikwad and Gomish Sharma, (2014), Study of Performance Characteristics of Compression Ignition Engine Fuelled with Blends of Biodiesel fromUsed Cottonseed Oil,

International Review of Applied Engineering Research, Volume 4, Number 3, pp. 289-296.