Experimental Study of Emission and Performance of Single Cylinder Diesel Engine Running On Groundnut Oil Based Biodiesel

G.VENKAT SUNDARAM, Dr.S.THIRUMALINI

Abstract— The primary objective of this project was to study the effect of Groundnut Oil based Biodiesel on a CI engine operating at a constant speed under a range of loads. Biodiesel is being considered nowadays as an alternative to Petro-diesel, with advantages in favor of Biodiesel being it's lowered emissions and performance comparable to diesel. This experiment was done by synthesizing Biodiesel from Groundnut oil and mixing it in different ratios with diesel to run a Single Cylinder Field Marshall Diesel engine and thereby obtaining the different performance and emission characteristics for the Biodiesel.

Index Terms— Biodiesel, Biofuel , Groundnut Oil, Trans-esterification, Diesel Emission test ,NOx emissions, Specific Fuel Consumption, HC emissions, CO and CO_2 emissions.

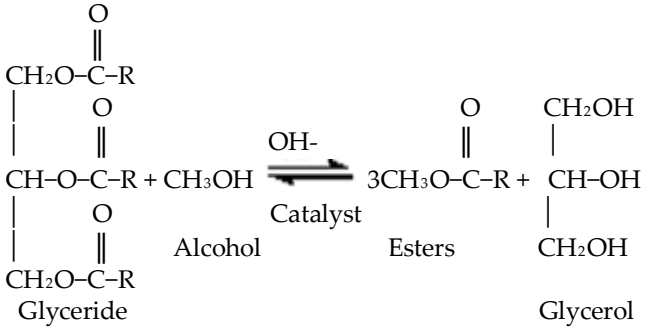
1 INTRODUCTION

The current scenario in the world is depletion of fossil reserves owing to the extended use of petroleum based fuels. Petroleum based fuels have been the driving force of the World's energy source and their gradually depleting amount threatens their capacity to meet the energy requirements [1]. In developing countries of the world such as India where the Petroleum fuels impact highly the economy via its dependence for transportation of all goods and services, an alternate means of fuel/energy is the need of the hour. Hence the researches into alternate fuels such as Biodiesels that can substitute diesel fuel are being researched extensively [2]. A large number of studies have also been undergone into the Biodiesels using different oils such as Coconut Oil [3], Nerium oil [4], Cottonseed oil [5], Jatropa oil [6], Linseed oil [7], Palm oil [8], etc and a comparatively low cost option that utilises the waste/used cooking oil. These Biodiesels come with their own advantages and disadvantages. The biggest drawback towards large scale development of Biodiesel as an alternative fuel is the large production cost associated with it. An alternative is to use waste cooking oil for producing Biodiesel [9]. This could be a cost effective solution to Biodiesel production, but it is not without it's own drawbacks such as reduced quality of Biodiesel, problem of filtration before making Biodiesel, etc.

Biodiesels by definition are the fuels that are derived from vegetable oils or animal fat through a process known as transesterification. Biodiesels generally tend to have better Performance and Emission parameters compared to diesel fuels. The obtained Biodiesel is used as fuel by mixing it appropriate ratios (depending on the properties of obtained Biodiesel) with petroleum-derived diesel, partially due to the operational problems that occur when it is directly used as fuel (This is also the case with vegetable oils which prevent them from being directly used as fuel). In the production process the influence of factors such as environment conditions, reactants and reaction parameters, catalysts, etc, [10] on the Biodiesel production is critical. Even after production the Biodiesel is, by virtue of its physical properties, similar to oil from which it is produced and so its freezing point remains close to that of oil used. This leads to problems during storage and use in cold weather or low temperature conditions. There is also a need to apply special coating to engine parts of conventional CI engines using Biodiesel as substitute for diesel because properties of Biodiesel whereby they may clog/ otherwise adversely affect the engine parts. Nevertheless, Biodiesel is being researched as a viable alternative to Diesel as a cleaner and more efficient fuel.

2 BIODIESEL PRODUCTION

Groundnut oil that was commercially available was used as the base oil preparing Biodiesel. The first step in the process of making Biodiesel is Trans-esterifiction.Trans-esterification is a chemical reaction in which vegetable oils and animal fats are reacted with alcohol in the presence of a catalyst. The equation is as given below



Transesterification equation

The products of reaction are Esters and Glycerol. These Esters form the Biodiesel. In this experiment, first the 1000 mL of Oil was heated upto 65^0C and then allowed to cool down. During this time the mixture of 200mL Methanol (alcohol) and 3.5g NaOH (Sodium Hydroxide) catalyst was prepared and the product was Sodium Methoxide. This Sodium Methoxide was added to the Oil and continuously stirred. At the end of reaction time, mixture was given a standing time to allow for layer separation by gravity. The mixture was allowed to stand for upto 48 hours. The layers separate into Biodiesel at top and Glycerol at bottom.

The Biodiesel that was separated was washed with an equal amount of warm water to remove the excess methanol and other impurities in the Biodiesel. The Methanol gets dissolved in water and is drained and the remaining content was the Biodiesel that can be used for experiment.

3 EXPERIMENTAL SETUP

The experiment was carried out in a Single Cylinder Field Marshall CI Engine operating at a constant speed of 1000 rpm. The engine was not given a protective coating so as to also explore the feasibility of it's commercial application. Hence the tests were done for mixtures upto 50 percentage ratio of Biodiesel to Diesel only as any more could lead to clogging of the engine parts. The Specification of the engine is given in Table 1. The setup was arranged as given in Fig 1.

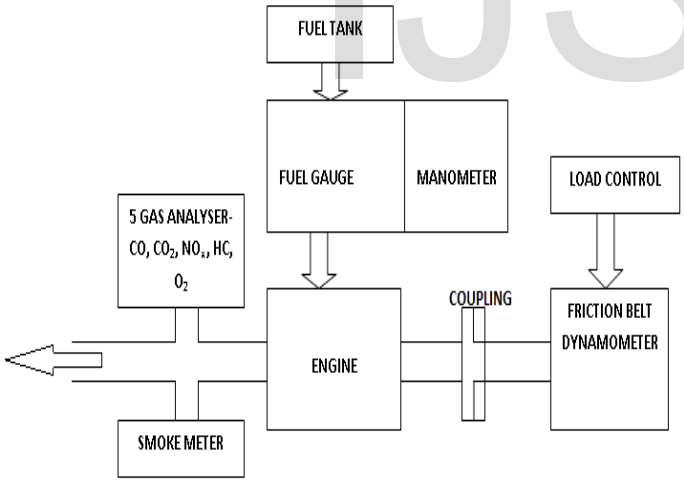


Fig 1 The Experimental Setup

The prepared Biodiesel was mixed with pure diesel in the various ratios required for conducting the experiment. These are usually expressed as percentage (%) of total volume. For example; B10 denotes that the % concentration of Biodiesel in the mixture is 10% and the rest 90% is diesel. Like this different ratios such as B10, B30, and B50 were prepared. Each time the density of fuel was noted and the flash points were determined.

Table 1. Engine Specifications

Engine Model	Field Marshall
Cylinders	Single
Engine Parameter	Value
Rated Power	10HP/7.35 kW
Rated Torque	1.17 Nm
Speed	1000 rpm
Bore	114.3mm
Stroke	139.7mm
Drum Radius	102mm

4 PERFORMANCE TESTS

The performance tests were conducted for the different fuel blends and the different performance parameters were obtained and corresponding graphs were plotted. The results obtained were comparable to studies done for the same [4], [5], [7], [11], [12].

4.1 Specific Fuel Consumption or SFC (in kg/kWh)

The graph between Specific Fuel Consumption and Brake Power is plotted as shown in Fig. 2. The different blends of Biodiesel seem to show lower SFC for a corresponding value of Brake Power than for Pure Diesel. This means that Biodiesel use less fuel to produce same amount of Brake Power. Furthermore, the SFC decreases as the concentration of Biodiesel increases. Thus we can say that `Higher the Biodiesel Concentration, Lower the SFC`.

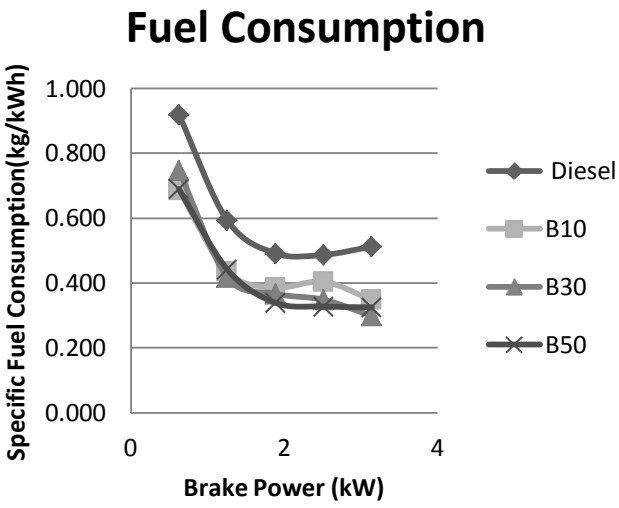


Fig 2 Plot of Specific Fuel Consumption vs. Brake Power for Different Biodiesel Blends.

4.2 Exhaust Temperature (in ^{0}C)

The graph between Exhaust Temperature and Load is plotted as shown in Fig. 3. It was found that the Exhaust Temperature of the engine decreased as the Biodiesel concentration increased. Comparing with diesel the blends seem to have higher temperature than diesel at lower loads and lesser temperature at/ near full load conditions and was in line with many papers conducted for this parameter.

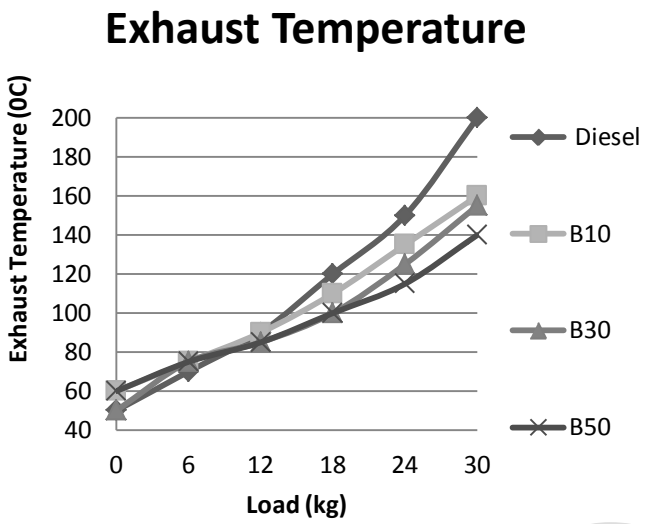


Fig 3 Plot of Exhaust Temperature vs. Engine Load for Different Biodiesel Blends.

5 EMISSION TESTS

These were done in tandem with Performance Tests for the engine under test. Emission Characteristics were measured using a 5-gas analyzer (for measuring NOx, CO, CO_2, and HC) and a Smoke Meter. The corresponding graphs were plotted to compare the emission characteristics for each blend of Biodiesel. As with the performance characteristics the results obtained were comparable to studies done for the same [4], [5], [7], [11], [15].

5.1 NO_x Characteristics

NOx occurs when the temperature rises in the cylinder causing formation of NO. There are many factors that affect the formation of NOx inside the combustion chamber [14].The obtained NOx Characteristics are as shown in Fig.4. It was found that compared to diesel the Biodiesel blends have lower values and this decrease is more when Biodiesel concentration is increased. Higher NOx can be attributed to lower exhaust temperature of blends that could have reduced the rate of formation of NOx.

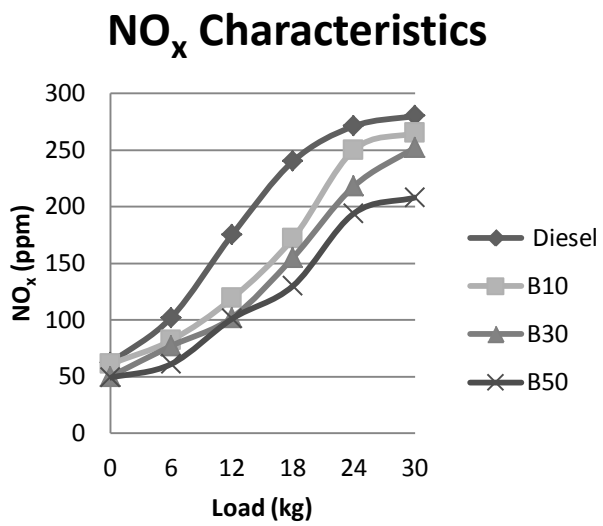


Fig 4 Plot of NOx emission vs. Engine Load for Biodiesel Blends.

5.2 HC Characteristics

The HC emissions of the engine under test were as shown in Fig. 5. There was found to be not much change in HC characteristics as in general the HC emissions are almost negligible in case of Diesel Engines.

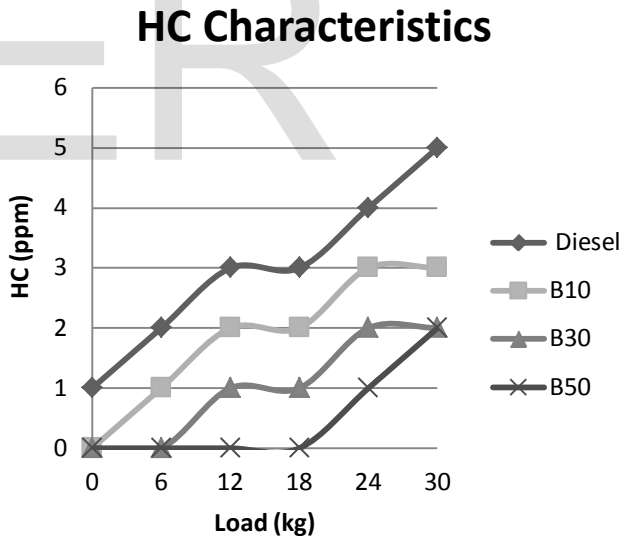


Fig 5 Plot of HC emission vs. Engine Load for Biodiesel Blends

5.3 CO & CO_2 Characteristics

The CO & CO_2 graphs were as plotted in Fig. 6 and Fig. 7. Though the CO emission for diesel itself is very low, the emission for Biodiesel blends was found to be even significantly lower than that. The CO_2 emissions on the other hand were an entirely different matter. Though emissions for Biodiesel blends were lower than diesel the variation was not significant except at part loads and the variation again shrunk at Full load. Also the emissions increase with increase in Biodiesel concentrations.

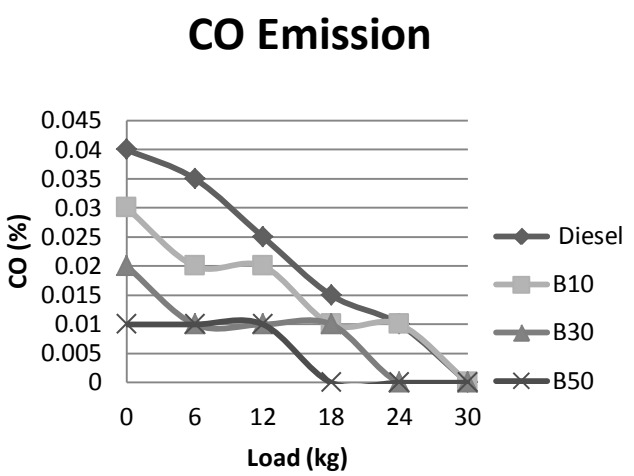


Fig.6 Plot of CO emission vs. Engine Load for Biodiesel Blends

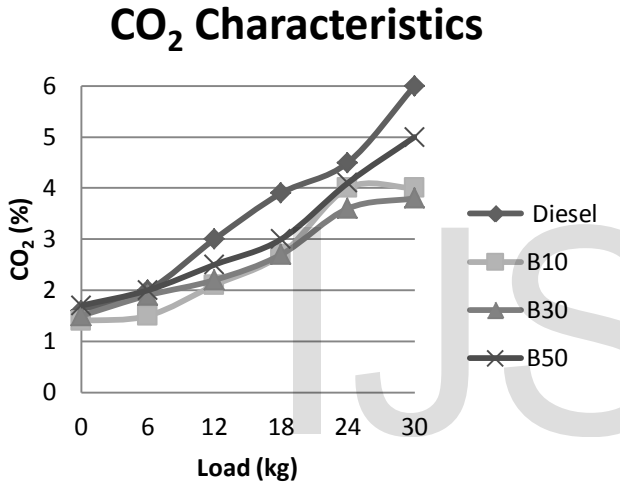


Fig.7Plot of CO_2 emission vs. Engine Load for Biodiesel Blends

5.4 Smoke Characteristics

Smoke characteristics are as shown in Fig.8. Smoke has an inverse relation with NO_x and hence when NO_x is less, smoke emissions become more. At the initial state smoke of Biodiesel blends is high, but still less than Diesel. This smoke can be attributed as startup smoke. At higher loads, smoke emissions increase as NO_x increases, but also the increase in Biodiesel concentration increases the smoke emissions. This could be due to increased CO_2 concentrations in the exhaust.

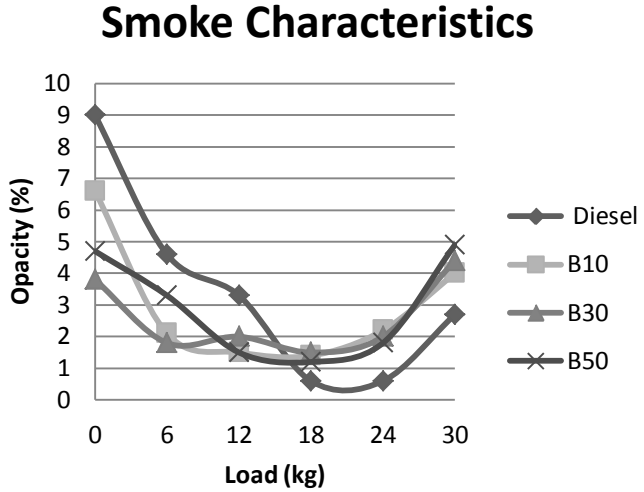


Fig.8 Plot of Smoke emission vs. Engine Load for Biodiesel Blends

CONCLUSION

1) This experiment gave a Biodiesel that had lowered NO_x emission compared to diesel for the engine under test.
2) Increasing Biodiesel concentration seems to reduce the NO_x emissions as well as fuel consumption but increases smoke emissions.
3) At full loads higher Biodiesel concentrations result in higher CO_2 emissions. Same seems to be the case for HC.
4) Possible applications for this Biodiesel can be low power engine such as the one under test for this experiment, but further study is needed with more ratios to reach a conclusive proof of best blend.

REFERENCES

[1] Prospects of biodiesel for future energy security-S.V.A.R.Sastry, Ch.V.Ramachandra Murthy-2012 Elixir Chem. Engg. 53 (2012) 12029-12034 Available online at www.elixirpublishers.com(Elixir International Journal)

[2] The Status of Biodiesel as an Alternative Fuel for Diesel Engine – An Overview- S.Jaichandar and K.Annamalai-Journal of Sustainable Energy & Environment 2 (2011) 71-75

[3] Determination of Optimum Catalyst Concentration for Biodiesel Yield from Coconut (Cocos nucifera) Oil-A.U.Ofoefule, C.N.Ibeto and I.E.Ugwuamoke- International Research Journal of Pure & Applied Chemistry, 3(4): 357-365- 2013

[4] Performance and Emission Evaluation of a DI Diesel Engine Using Nerium Oil as Alternative Fuel-K.Suresh Kumar,G,Guruvaiah Naidu, A.Venkata Vishnu-International Journal of Engineering Research & Technology (IJERT) Vol. 2 Issue 9, September – 2013 ISSN: 2278-0181

[5] Performance And Emission Characteristics On 4-Stroke Single Cylinder C.I.Engine Using Cottonseed Bio Fuels-R.Senthil Kumar, R.Manimaran- 2013 Dodiya et al,International Journal of Advanced Engineering Research and Studies E-ISSN2249–8974

[6] Jatropa—The future fuel of India-R.D.Misra, M.S.Murthy-2010- journal homepage:www.elsevier.com/locate/rser

[7] Performance And Emission Characteristics Of Direct Injection Four Stroke Diesel Engine Operating On Linseed Oil And Diesel Oil Blend-Mr. Kanji D.Dodiya, Mr. Gaurav P. Rathod-2013- Dodiya et al,International Journal of Advanced Engineering Research and Studies E-ISSN2249–8974

[8] Ultrasonic method of Biodiesel production from Palm kernel- O.K.Onanuga and J.O.Coker- Journal of Applied and Natural Science 5 (1): 1-4 (2013)

[9] Biodiesel production from waste cooking oil via alkali catalyst and its engine test - Xiangmei Meng, Guanyi Chen,Yonghong Wang- Fuel Processing Technology 89 (2008) 851–857,available at www.elsevier.com/locate/ fuproc

[10] Biodiesel production process optimization and characterization to assess the suitability of the product for varied environmental conditions -T. Eevera, K. Rajendran, S. Saradha-2008-Journal homepage: www.elsevier.com /locate/renene

[11] Variation Of Engine Performance And Emissions Using Biodiesel Fuels- Abdullah Abuhabaya, John Fieldhouse, David Rob Brown- University of Huddersield, Queensgate, HuddersfieldHD1 3DH, UK -2010

[12] Experimental Investigation on Engine Performance of Diesel Engine Operating on Peanut Seed Oil Biodiesel Blends – Hanchate Suresh Babu Rao, B.Venkatesh, Dr.T. Venkateswara Rao, K. Hema Chandra Reddy-2013

[13] The performance characteristics of groundnut (Arachis hypogea, L.) biodiesel in a diesel engine- Oluwole Oluwatoyin ONIYA and Adeleke Isaac BAMGBOYE- African Journal of Environmental Science and Technology, Vol . 7(6), pp. 504-517, June 2013

[14] Root Cause Analysis of Changes in NO_x Emissions due to Biodiesel Combustion in Diesel Engines- Sergio Capareda (co-PI), Jerald A. Caton (co-PI), Timothy J. Jacobs (PI)- 2009

[15] Biodiesel Production and its Emissions and Performance: A Review- Ambarish Datta and Bijan Kumar Manda- International Journal of Scientific & Engineering Research,Volume 3, Issue 6, June-2012

- *Author name is G.Venkat Sundaram, currently pursuing Masters of Technology in Automotive Engineering in Amrita School of Engineering, Amrita Vishwa Vidyapeetham, Coimbatore, Tamil Nadu, India, PH-07293519520, Email: venkat.g_1990@live.com*
- *Co-Author name is Dr.S.Thirumalini,Chairman and Professor, Dept. of Mechanical Engineering, Amrita School of Engineering, Amrita Vishwa Vidyapeetham, Coimbatore, Tamil Nadu, India.*