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Experimental Study on Diesel Engine Performance Using Undi Oil Biodiesel and Its Blends

#1S. A. Ransing, #2M.H. Attal

[1]shivransing.10@gmail.com
[2]mhattal.scoe@sinhgad.edu

[1]Mechanical Engineering Department, Sinhgad College of Engineering, Pune, Maharashtra, India
[2]Mechanical Engineering Department, Sinhgad College of Engineering, Pune, Maharashtra, India

ABSTRACT

There has been continuous depletion of fossil fuel sources across the world and emission norms are becoming stringent. These have caused the researchers to find alternative fuels for internal combustion engines. Biodiesel (fatty acid methyl/ethyl ester) which is derived from triglycerides by transesterification, presents hopeful option as a renewable, biodegradable fuel. Biodiesel used here is undi oil. Undi oil is blended with diesel in different proportion. Blends properties have been tested by ASTM D6751 standard. The test has been conducted on single cylinder four stroke constant speed diesel engine using pure diesel, 10%, 20%, 30%, 40% and 100% blends. The engine model has been validated using GT-Power simulation software. Diesel engines emit significant amounts of particulate matter (PM) and oxides of nitrogen (NO_x). They also emit small percentages of hydrocarbon (HC) and carbon monoxide (CO). It is seen that use of biodiesel as an alternate fuel in CI engine reduces CO, HC and smoke emissions but increases NO_x emission due to higher oxygen content of biodiesel as compared to diesel. Performance curves such as brake thermal efficiency (BTE), brake specific fuel consumption (BSFC) have been plotted for pure diesel and blends. Performance results for B20 (20% undi oil and 80% diesel) follow closely to that of pure diesel. The aim of this project is to experimentally investigate the effect of biodiesel and its blends on CI engine performance.

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I. INTRODUCTION

Increasing environmental pollution and continuous consumption of fossil fuels have caused researchers to find alternative fuels for Internal Combustion engines. The alternative fuels are biodiesel, natural gas, alcohols, etc. Biodiesel (fatty acid methyl/ethyl ester) which is derived from triglycerides by transesterification, presents hopeful option as a renewable, biodegradable fuel. Diesel engine is better power source due to higher efficiency, performance and fuel economy than spark ignition (S.I.) engine. Compression ignition (C.I.) engine produce exhaust gas which is a mixture of undesirable products known as pollutants. The use of biodiesel in diesel engine requires small or no modification. Many researchers studied that use of biodiesel in diesel engine produce higher NO_x emission compared to diesel.

N. Dagar and I. H. Shah [2] investigated two cylinder diesel engine operations with EGR. They found that the exhaust gas temperature of engine with diesel as fuel to be lower than biodiesel and its blends with constant EGR rate. The brake thermal efficiency and specific fuel consumption of diesel engine with biodiesel and its blends were found to be higher than diesel as fuel with 15% EGR rate.

B. Pattanayak et al. [3] analyzed CI engine performance and emission using Karanja oil methyl ester with exhaust gas recirculation process. B20 of Karanja biodiesel shows the best performance characteristic in case of the blended fuels. With increase in percentage of blending the performance characteristic deteriorates as calorific value of biodiesel is less than diesel fuel. The use of biodiesel and its blends reduces CO and HC and increases the NOx emission. Using EGR technique BSFC goes on increasing and BTE of the engine decreases.

An Puzun et al. [4] studied particle size distributions in common rail diesel engine using biodiesel blends. They concluded that the number of particles in nucleation mode increases with increase of biodiesel and the accumulation mode particles of a size > 50nm decrease. With increase in load, nucleation mode particles decrease. Most of the particulate emissions are less than 300nm.

R. Bawane et al. [5] tested CI engine performance using undi oil biodiesel for different blends. BTE is decreased and BSFC are higher for biodiesel and its blends than that of diesel. The HC emission gives decreasing trend with increase in compression ratio for the entire range of fuels.

K. Rajan , K. R. Senthilkumar [6] have studied Exhaust Gas Recirculation (EGR) impact on Emission Characteristics and the Performance of Diesel Engine with Sunflower Oil Methyl Ester. Compared with conventional diesel fuel, they found that at 20 % biodiesel blends ,the NO_x emission reduces about 25% with 15% EGR due to lower oxygen available in the and the flame temperature in the combustion chamber lowrers down.

K. Muralidharan and D. Vasudevan et al. [7] evaluated combustion characteristics and Performance testing of variable compression ratio engine. The fuel used was methyl esters of waste cooking oil and diesel blends. Compared with the conventional standard diesel at compression ratio 21.It has been found that the performance of the B40 blend is better. At lower and medium percentages, waste cooking oil methyl ester is hopeful substitute for diesel fuel.

M. M. Rahman et al. [8] evaluated alternative fuels effect on particle emission from a common-rail diesel engine. Ethanol up to 30% substitution reduces PM and PN consistently. Among all used alternative fuels, biodiesel reduces PM most. Canola biodiesel increased PN and tallow biodiesel reduced PN with 15 nm reduction in particle median diameter.

Xinling Li et al. [9] studied exhaust gas recirculation (EGR) impact on soot reactivity from a diesel engine. Combustion duration increases as EGR rate increases. BSFC and soot emission also increases with EGR rate. Low organic carbon fraction and highly ordered graphitic structure in the particle sample are reasons for the decrease of soot reactivity.

Researchers [10-13] studied performance of diesel engine fuelled by a biodiesel extracted from waste cocking oil, karanja oil and linseed oil. Waste vegetable oil has been found to be safe and efficient alternative fuel. It has a low impact on the environment. Small percentage upto 20% blend can be used in diesel engine without any modification.

A. E. Atabani, Aldara da Silva César [14] did study on Calophyllum inophyllum- non-edible biodiesel feedstock. Crude Calophyllum inophyllum oil came out as highly acidic. A two-step of acid–base catalyzed transesterifi-cation process used to produce biodiesel from feedstock. Studies show that higher biodiesel percentage tends to decrease CO , HC, power and increase BSFC and NO_x.

II. BIODIESEL PRODUCTION

The steps in biodiesel production process are mentioned below.

A. Transesterification

The major components of animal fats, vegetable oils are triglycerides. The vegetable oil or animal fat is undergone through a chemical reaction known as transesterification as shown below.

$$\begin{array}{l} CH_2OCOR''' \\ \quad | \\ CH_2OCOR'' \\ \quad | \\ CH_2OCOR' \end{array} + 3ROH \xrightarrow{\text{Catalyst}} \begin{array}{l} CH_2OH \\ \quad | \\ CH_2OH \\ \quad | \\ CH_2OH \end{array} + \begin{array}{l} R'''COOR \\ \quad | \\ R''COOR \\ \quad | \\ R'COOR \end{array} \qquad (1)$$

Oil or Fat   Alcohol   Glycerin   Biodiesel

Chemical process of which transforms large, triglyceride molecules of fats, edible oils into smaller molecules, similar in size to the molecules of the species present in diesel fuel is transesterification.

1) Filtering: Filter the vegetable oil to remove solid particles from it. You may have to warm it 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: Heat the oil first to remove the water content. Vegetable oil will probably contain water, which can slow down the reaction and causes saponification (soap formation). Raise the temperature to 100°C, hold it there and allow water contents to boil off. The agitator is run to avoid steam pockets forming below the oil and exploding. Drain water out from the bottom as they form, one can save oil coming out with the water.Increase the temperature to 130°C for 10 minutes and allow it to cool

Fig.1 Pure Biodiesel Produced

B. Preparation of Blends

The amount of biodiesel available is less than that of diesel. The biodiesel is blended with diesel by volume as B10 (10% undi biodiesel & 90% diesel fuel), B20 (20% undi biodiesel & 80% diesel fuel), B30 (30% undi biodiesel & 70% diesel fuel), B40 (40% undi biodiesel & 60% diesel fuel, B100 (100% undi biodiesel & 00% diesel fuel).

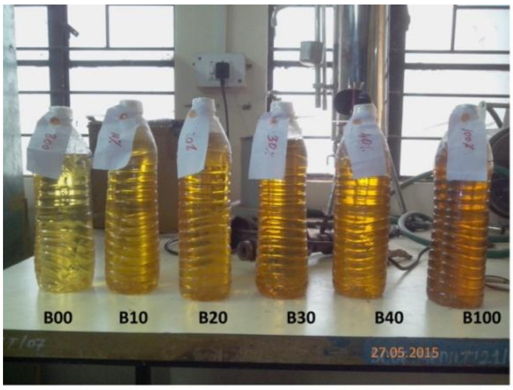

Fig.2 Blends of Undi Biodiesel

C. Fuel properties

Fuel properties of pure diesel and undi oil biodiesel are shown in following table.

TABLE I
Properties of Diesel and Undi Oil

Properties	Diesel	Undi oil
Density at 15°C(gm/cc)	0.834	0.874
Kinematic viscosity at 40°C (cst)	1.90	4.16
Flash Point (°C)	44	154
Calorific Value (MJ/Kg)	42.5	38.5

III. EXPERIMENTAL SETUP AND PROCEDURE

To carry out the present study, a diesel engine coupled with an alternator is selected. From the head difference in the manometer, air flow rate is calculated. The fuel consumption of an engine is measured by determining the time required for consumption of a given volume of fuel. The mass flow rate of fuel consumption is determined by the multiplication of volumetric fuel consumption and density. In the present set up, volumetric fuel consumption has been measured by using a glass burette and stop watch.

The engine is run initially with pure diesel as fuel and corresponding readings are noted down. Graphs are plotted for brake thermal efficiency (BTE) and brake specific fuel consumption (BSFC) versus brake power. The different biodiesel blends such as B10, B20, B30, B40 and B100 are used to carry out test on diesel engine. BTE and BSFC results are calculated for all blends. In engine performance analysis graphs of BTE Vs Power, BSFC Vs Power have been plotted for diesel fuel and biodiesel blends. Comparison of engine performance using blends is done with engine performance using diesel.

Fig. 3 Experimental setup

The following table shows experimental components.

TABLE II
Engine Components

1. Engine	5. Fuel Tank
2. Manometer	6. Burette with valve
3. Air box	7. Exhaust pipe
4. Air filter	8. Alternator

The layout of experimental setup is shown in following figure.

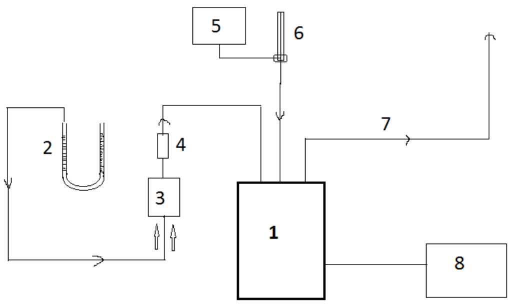

Fig.4 Schematic Diagram of Experimental Setup

IV. EXPERIMENTAL RESULTS

The following graphs have been plotted from experimental results. They show variation of brake thermal efficiency and brake specific fuel consumption versus load.

A. Engine Performance Analysis

The engine performance analysis is as follows,

1) Brake Thermal Efficiency: Brake thermal efficiency (BTE) is an important parameter to measure engine performance. Thermal efficiency increases with load and reaches maximum value at full load. Thermal efficiency for mineral diesel is higher than that of other blends. As blends percentage increases, BTE decreases. Relatively higher viscosity and poor volatility of biodiesel causes poor atomization and gives comparatively incomplete combustion.

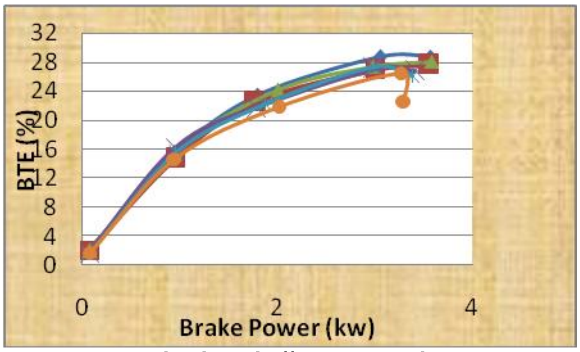

Fig. 5 Brake Thermal Efficiency Vs Brake Power

2) Brake Specific Fuel Consumption: Brake specific fuel consumption (BSFC) is another parameter considered in engine performance analysis. Fig.6 shows variation of BSFC versus brake power for different biodiesel blends. Brake specific fuel consumption decreases within increase in brake power. BSFC increases with increasing percentage of biodiesel. Biodiesel has higher viscosity and density than pure diesel. Also biodiesel is having lower calorific value than that of diesel. This is reason for increased fuel consumption with increasing blend percentage.

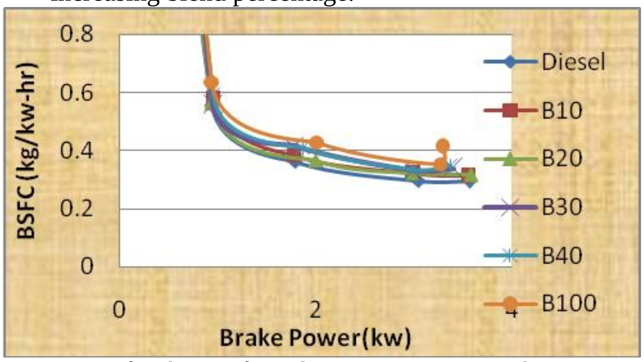

Fig. 6 Variation of Brake Specific Fuel Consumption versus Brake Power

V. SIMULATION RESULTS

The following graphs have been plotted using GT-Power simulation results.

Engine Performance Analysis

Brake Thermal Efficiency: Brake thermal efficiency (BTE) increases with load. The graph shows variation of BTE versus different power output for different blends. Thermal efficiency decreases with increasing percentage of biodiesel in blend.

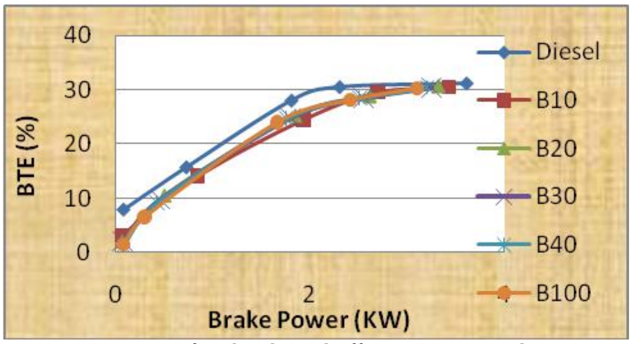

Fig. 7 Variation of Brake Thermal Efficiency versus Brake Power – simulation

Brake Specific Fuel Consumption: Fig. 8 Shows variation of brake specific fuel versus power consumption for different blends. Lower calorific value of biodiesel than diesel is reason for increased fuel consumption. BSFC shows decreasing tend with increase in power output. BSFC increases with biodiesel percentage.

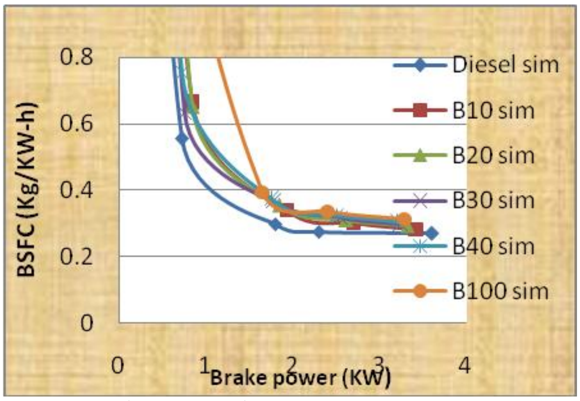

Fig. 8 Variation of Brake Specific Fuel Consumption versus Brake Power- simulation

Engine Emission Analysis

Following graphs show variation of oxides of nitrogen, hydrocarbon for different blends.

Oxides of Nitrogen (NO_x): Nitrogen oxides emission increase with load. The fig. 9 Shows variation of NO_x versus different power output for different blends. As load increases, combustion temperature also increases. Hence, NOx also increases. NOx increases with biodiesel percentage because biodiesel contains relatively more oxygen than that of pure diesel.

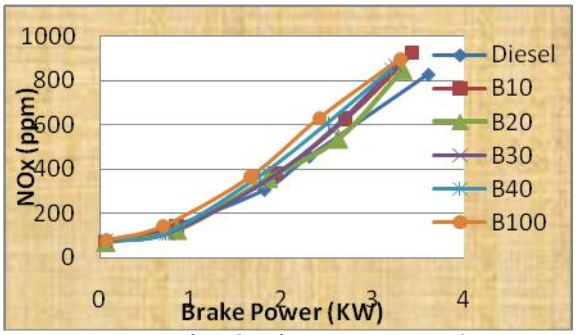

Fig. 9 Variation of Oxides of Nitrogen versus Brake Power

Hydrocarbon (HC): Fig. 10 Shows variation of hydrocarbon emission versus power for different blends. As load increases, power output increases. At higher load, more amount of fuel is injected and therefore air-fuel ratio is changed. Rich mixtures are formed at some locations inside combustion chamber. Hydrocarbons form due to incomplete combustion of fuel. As biodiesel percentage increases, hydrocarbon decreases because biodiesel contains more oxygen than diesel which helps for complete combustion.

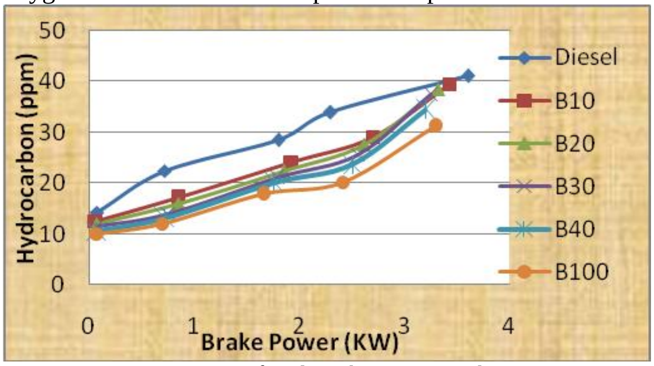

Fig. 10 Variation of Hydrocarbon versus Brake Power

VI. CONCLUSION

Raw undi oil has more free fatty acid (FFA) contain in it. When oil is undergone through transestrification process, FFA contain in it decreases and viscosity of oil also drops down. The use of undi oil and its blends as alternative fuel has been studied. It is seen that undi biodiesel can be used in diesel engine without any modification. Blends such as B10, B20, B30, B40 and B100 have been used to carry out test on single cylinder diesel engine and performance parameters are calculated. The BTE and BSFC graphs show that, among all blends B20 blend follow closely to that of pure diesel. From experimental results, B20 blend shows 2.51% variation in BTE and 7.17% variation in BSFC at maximum power when compared with that of pure diesel. The engine model has been validated using GT-Power simulation software. The experimental results for BTE and BSFC of pure diesel and B20 blend vary within 10% when compared with that of simulation results. Simulation results of emission show that NOx emission increases and HC emission decreases with increase in percentage of biodiesel in blend.

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