Analysis of Performance and Emission Parameters on Diesel Engine Using Various Blended Bio-Fuels

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Abstract: ***Bio-fuels are proved to be very good substitutes for the existing petroleum fuels. Biodiesel can be extracted from vegetable oils and waste fats. Trans-esterification is simply described as the chemical breaking of oil using alcohol to form alcohol esters and glycerol. This procedure involves a three step process, acid, alkaline esterification and washing based on FFA content. Then methyl esters of fuel (Soybean Oil, Rapeseed Oil, Tamanu Oil, and Corn Oil) have been blended with diesel fuel in various proportions to check the properties for theoretical investigation. The scope of the technology is to provide utility and comfort with no damage to the user or to the surroundings. In this study, the performance and emissions of single cylinder, four stroke, diesel engine operating on diesel and biodiesels have been investigated theoretically using the simulation software Diesel-RK and experimentally in a IC Engine. As a result, the blends B30 SME and B30 Tamanu oil methyl ester have shown a better performance. All blends show reduction in HC, NOx with increase in load. This is due to higher cetane number, calorific value and oxygen content. But, CO has slightly increased than the diesel fuel at all load condition. From Experimental investigations, blending of Tamanu oil methyl esters up to 30% with diesel fuel can be used without any hardware modification in diesel engine and it reduces the harmful emissions.***

Keywords: Diesel Engine, Biodiesel, DIESEL-RK, Theoretical Modelling, IC Engine Performance, Emissions, Trans-esterification, Soybean Oil, Tamanu Oil, Corn Oil, Rapeseed Oil

1. Introduction

Depleting mineral oil reserves and increasing cost of the petroleum products demands an intensive search for new alternative fuels. In recent years, there has been a considerable effort to develop and introduce alternative renewable fuels to replace conventional petroleum-based fuels.

A. Biodiesel as an Alternate Substitute for Diesel

Biodiesel refers to a vegetable oil or animal fat-based diesel fuel consisting of long-chain alkyl (methyl, propyl or ethyl)esters. Biodiesel is typically made by chemically reacting lipids (e.g., vegetable oil, animal fat) with an alcohol producing fatty acid esters and is meant to be used in standard diesel engines alone, or blended with diesel [3]. The esters of vegetable oils are popularly known as biodiesel. It is the process of reacting triglyceride with an alcohol in presence of a catalyst to produce glycerol and fatty acid esters. In India, attempts are being made for using non-edible and under-exploited oils for production of esters.

2. Extraction Of Biodiesel

Oil from dried and peeled Tamanu seed is extracted by an engine driven screw press. However, it must be noted that oil extracted by mechanical presses needs further treatment of filtering process and degumming.

A. Experimental Setup for Biodiesel Production

The setup shown in figure 1 is used in the acid and alkali esterification process consists of two necked round bottom flask to carry out the reaction, a magnetic stirrer with heater for continuous heating and stirring, water cooled condenser to restrict the evaporation of methanol during the heating process carried out in the two necked round bottom flask [4]. The two necked round bottom flask is partially immersed in to the bowl containing water in order to constantly distribute the heat. External water supply is provided for condenser to continuously cool the evaporated methanol from oil [4].

Figure 1: Trans-esterification Setup

B. Trans-esterification

Trans-esterification of a triglyceride typically consists of a series of consecutive reversible reactions. The triglyceride is converted stepwise into a diglyceride, a glyceride and finally a glycerol, with the removal of an alkyl in each step. The free fatty acid content is 19.6% by Gas Chromatography test [6]. Trans-esterification can do in two ways, either one step method or two step methods based on the FFA content [6].

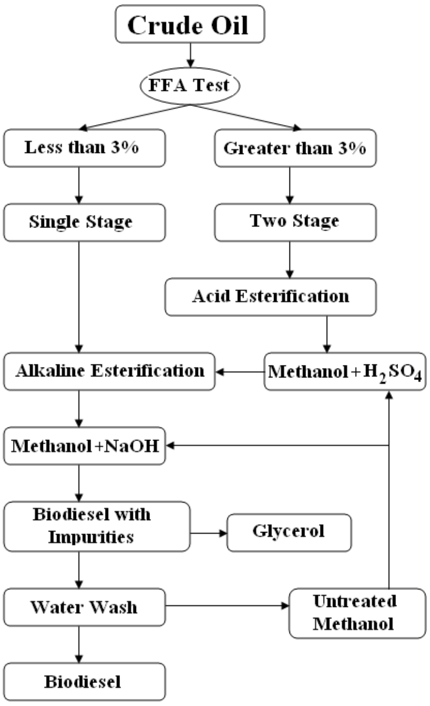

Figure 2: Trans-esterification Chart

C. Two Step Method

Since the percentage of FFA is more than 3%, the Transesterification process is by two step method [6]. The high percentage of FFA content makes difficulties in the alkaline Trans-esterification process due to soap formation. Therefore, two stages of procedure are adopted here. High FFA oil was converted to triglycerides in acid esterification process with methanol using anhydrous H_2SO_4 (acid catalyst). The oil is heated at 50_o-55_oC in a standard flask [6]. Methanol in the required quantity is taken and measured quantity of anhydrous H_2SO_4 is dissolved in it. The mixture is continuously stirred at constant speed and 60_oC for 2 hours to avoid methanol loss [1]. On settling, the excess methanol forms as the top layer and diglyceride remain as the bottom layer. The top layer is removed and diglyceride is collected. The bottom layer is used for the Alkaline Transesterification.

At second level, the separated oil from the separating funnel has to undergo Trans-esterification. Methoxide (methanol + sodium hydroxide) is added with the obtained ester and heated to 60°C for 1 hour with continuous stirring [1]. After the reaction, the glycerol is separated from the methyl esters.

D. Water Wash

The upper layer of alkali Trans-esterification product is removed and treated for the water wash to remove the impurities (like traces of glycerol, unused methanol, soap particles, etc.) from the biodiesel.

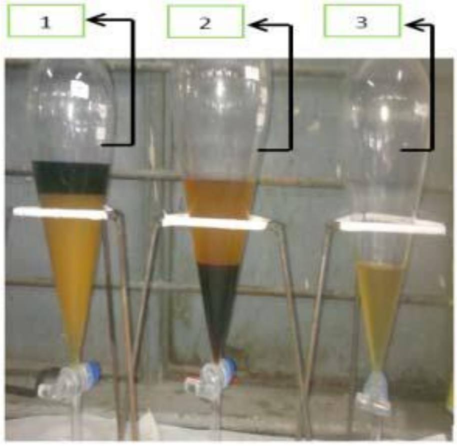

Figure 3: Trans-esterification Process

- Alkaline Esterification
- Acid Esterification
- Water Wash

3. Characterization of Tamanu Oil and its Blends with Diesel

A bomb calorimeter is used to measure the calorific value of various test fuels. Calorific values are 44500 KJ/Kg for diesel and 41450 KJ/Kg for Tamanu oil [8]. The kinematic viscosities of the different blends of tamanu oil and diesel fuels were determined by using a Redwood viscometer at room temperature. Pensky Marten's flash point apparatus was used to the determine flash and fire points.

Table 1: Yield obtained

Dried Fruit	2.5 Kg
Crude Oil Obtained	1.25 Litres
Methanol added	0.8 Litres
Biodiesel Obtained	1 Litres
Glycerol	0.2 Litres
Yield	80% Approx.

Table 2: Properties of Diesel and Tamanu oil

Properties	*Flash Point (°C)*	*Fire Point (°C)*	*Density (kg/m³)*	*Kinematic Viscosity (cSt)*
Diesel	65	84	0.86	3.06
Tamanu Oil	146	160	0.905	4.21
B10	72	96	0.865	3.12
B20	80	104	0.868	3.34
B30	86	118	0.873	3.57
B40	95	130	0.877	3.76

4. Experimental Setup For Testing Biofuel On Engine

Using esterified Tamanu oil in the compression ignition diesel engine at a rated speed of 1,500 rpm, the performance analysis is carried out. In every test, volumetric efficiency specific fuel consumption, air flow rate and cooling water temperature are measured with instrumentation provided on the engine.

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Figure 4: Engine Setup

The performance characteristics, combustion characteristics, and exhaust emission levels are performed at various operating conditions. The performance parameters were calculated from the fundamental relations between these measurements while varying the load on the engine from 0% to 100% in approximate steps of 25%. Cylinder, four stroke diesel, water cooled, power 5.2 kW at 1500 rpm, stroke 110 mm, bore 87.5 mm, 661 cc, and compression ratio of 17.5. It is coupled with Mechanical loading type. The test rig is provided with Piezo sensor to measure pressure of the engine cylinder online and the same procedure is repeated for other loads.

5. Performance Characteristic Curves

Performance curves have been drawn for various parameters like η_{bt}, η_{mech}, SFC, etc. as mentioned above. For the convenience of easy understanding biodiesel with diesel (Diesel, B10, B20, B30, and B40) have noted in all charts.

A. Brake Thermal Efficiency

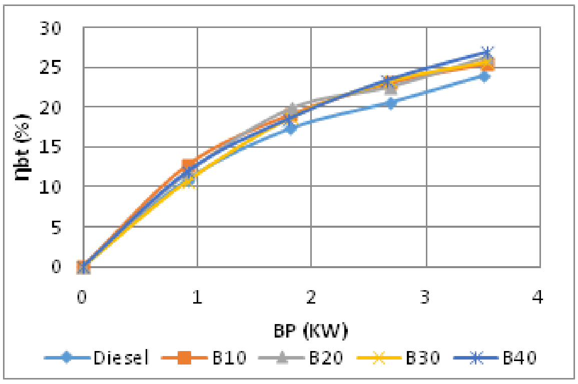

Figure 5: Brake Power Vs Brake Thermal Efficiency

Brake Thermal Efficiency is defined as brake power of a heat engine as a function of the thermal input from the fuel. It is observed from Figure 5, BTE of all blends are constantly increases based on the load condition and B40 have higher brake thermal efficiency.

B. Mechanical Efficiency

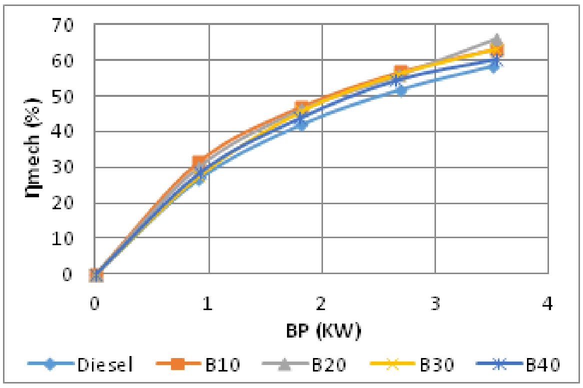

Figure 6: Brake Power Vs Mechanical Efficiency

Figure 6 shows that B10 have higher efficiency at various loads but at the full load condition B20 has the higher efficiency than the B10. Diesel fuel has little bit lag in the mechanical efficiency compared with that Biodiesel blends. This shows that the biodiesel lubricity have reduces the friction losses.

C. Specific Fuel Consumption (Sfc)

Among the blend B10 is lowest at all loads which is normally the optimum for any diesel engine. Hence SFC point of view B10 may be advantages. This is because of the combined effects of higher heating value and the lower fuel flow rate due to high density of the blends. Higher proportions of tamanu oil in the blends increases the viscosity which in turn increased the specific fuel consumption due to poor atomization of fuel.

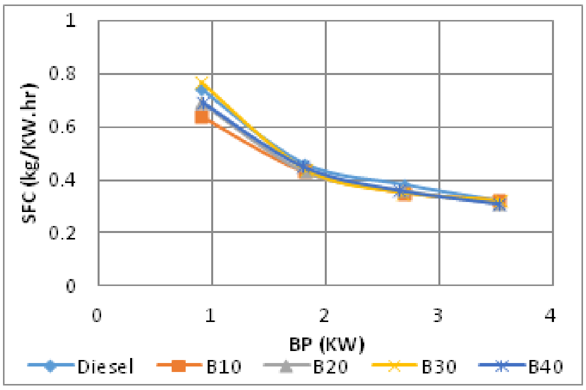

Figure 7: Brake Power Vs Specific Fuel Consumption

D. Fuel Consumption

It is observed from the Figure 8, Fuel consumption has increased in all load condition for diesel fuel. Among all other blends, B10 has the lower Fuel consumption rate. This is due to presence of oxygen content and the viscosity in the biodiesel. So, when the fuel blend ratio increases, viscosity of fuel also increases simultaneously.

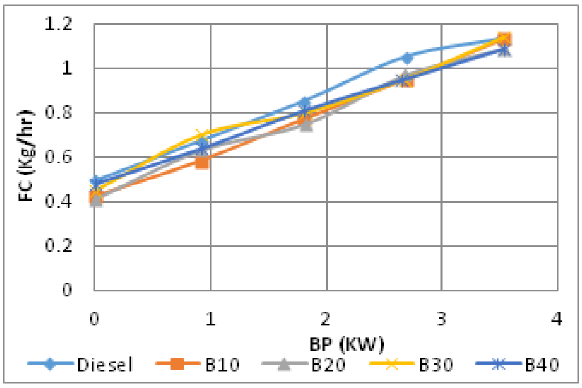

Figure 8: Brake Power Vs Fuel Consumption

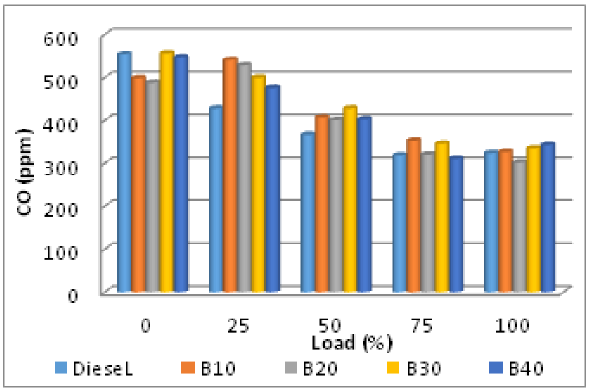

Figure 10: Load Vs Carbon Monoxide

6. Flue Gas Analyzer Kid

The schematic diagram for flue gas analyzer is drawn below Figure 9, the Gas analyzer kid consists of probe, hand set remote connection, and analyzer. While running the Diesel Engine, with the help of an analyzer kid the emissions such as carbon monoxide (CO), hydrocarbon (HC), nitrogen oxides (NO_x), carbon dioxide (CO_2), and oxygen (O_2) for Biodiesel blends and Diesel fuel can be measured.

Figure 9: Flue Gas Analyzer

7. Emission Characteristic Charts

Emission characteristics charts have been drawn using the values obtained from emission test. The variation in the volume of emissions such as CO, NOx and HC is shown for the various loads using the emission characteristic curves.

A. Carbon Monoxide Emission

From the Figure 10, Lower CO emission in the blends is probably due to higher oxygen availability in the fuel. B10, B20 has lower CO emissions when compared with petroleum diesel at full load. However, the results with higher blends are different with higher CO emissions at higher loads. Higher viscosity, improper spray pattern with higher blend percentage resulting in incomplete combustion may have increased the CO emissions.

B. CO_2 Emission

Figure 11, shows the emission levels of CO_2 for various blends and diesel. The test measurement reveals that the CO_2 emission for all blends expect B40 are less as compared to diesel at all loads. The rising trend of CO_2 emission with load is due to the higher fuel entry as the load increases. Biofuels contain lower carbon content as compared to diesel and hence the CO_2 emission is comparatively lower.

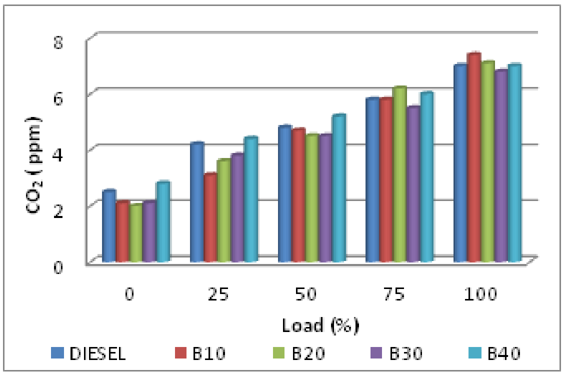

Figure 11: Load Vs Carbon Dioxide

C. Unburnt Hydrocarbons

Decreased Unburnt Hydrocarbon emissions clearly show that the combustion in the engine takes homogeneously. From Figure 12, it is very clear that increasing the blend percentage of tamanu oil decreases the UBHC emissions. All blends have shown lower UBHC emissions after about 75% load. This may be due to higher oxygen content as well as the higher cetane number. Physical properties of fuels such as density and viscosity influence the hydrocarbon emissions. Among the blends, B30 has lower UBHC emissions.

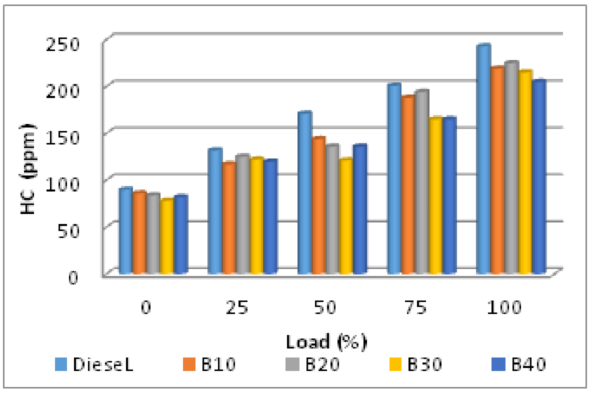

Figure 12: Load Vs Hydrocarbon

D. NO_x Emission

From the Figure 13, NO_x emissions for all blends are less as compared to diesel at all loads. This is probably due to lower combustion temperature in the engine cylinder with increasing load and blends. It is also observed that with increasing the percentage tamanu blends there is a trend of decreasing NOx emissions.

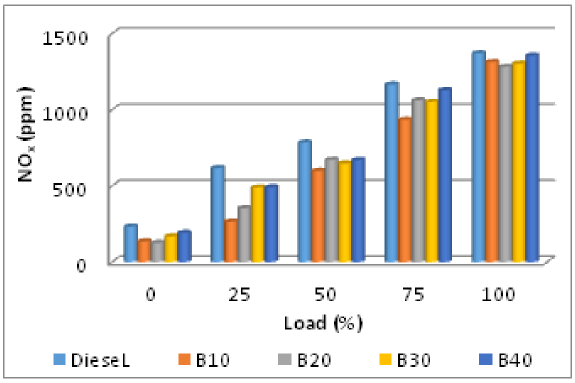

Figure 13: Load Vs Oxides of Nitrogen

E. Exhaust Gas Temperature From Engine

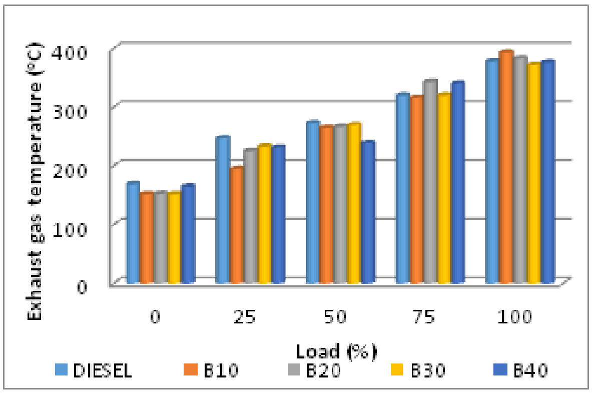

Figure 14: Load Vs Exhaust Gas Temperature

Figure 14 shows the variation of exhaust gas temperature with load for various blends and diesel. The results show that the exhaust gas temperature increases with increase in load for blends. At all loads, diesel and biodiesel are found to have the alternate lowest temperature and the temperatures for various blends show an upward trend with increasing concentration of tamanu oil in the blends. The biodiesel contains oxygen which enables the combustion process and hence the exhaust gas temperatures are higher. Moreover the engine being water cooled runs hotter which resulted in higher exhaust gas temperatures. But, among the blend B30 has the lower exhaust gas temperature than the diesel.

8. Conclusion

The following conclusions are drawn from the investigation:

1) The present analysis developed a two stage esterification procedure to produce biodiesel from Tamanu oil.
2) The specific fuel consumption is slightly lower than diesel for B10, B20 but closer to diesel when increase the load.
3) Blends up to 30% substantially reduce CO_2 emissions with a marginal increase in brake thermal efficiency and also it decreases the HC, and NO_x emissions with increase in load
4) Experimental Investigations show that *blending of Tamanu methyl esters up to 30 % (B30) with diesel* for use in an unmodified diesel engine is viable and it reduces the harmful emissions

9. Future Scope

1) Biodiesel, especially for the blends with a large portion of diesel, is technically feasible as an alternative fuel in CI engines with no modifications to engine. For environmental reasons, their popularity may soon be high.
2) The further improvement in optimization of Tamanu Oil production should be performed in the future to promote its properties and quality. And the further development in additives which improve consumption of biodiesel should be needed to increase performance and reduce emissions.

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