Performance, combustion and emission characteristics of a diesel engine fuelled with biofuel and oxygenated additives

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Abstract: The entire world has been seeing a continuous surge in the number of automobiles globally. This has further lead to a severe increase in the consumption of fossil fuels such as diesel, petrol, natural gas, etc. Biofuel can serve as a viable alternative to conventional fossil fuel made from renewable resources, such as edible as well as non-edible vegetable oils. This paper focuses on various studies related to the performance, combustion and emission characteristics of a diesel engine fuelled with Simarouba oil as the bio fuel and Isobutanol as the oxygenated additives. The experiments were carried out on a 4-stroke, single cylinder diesel engine by varying load. Extensive research work is being done in this field using a variety of biofuels. Bio fuels are nothing but the fuels that are obtained from plants to be used in Internal Combustion engines which in turn have the added advantage of lower emissions to that of conventional diesel and gasoline. Simarouba oil blends had been used in direct injection compressed ignition engine as an alternate fuel that has similar properties of diesel.

1. Introduction

From the various tests that were conducted by Devan et al using neat poon oil (Sterculia foctidn) and its blends with diesel fuel on a single cylinder 4-stroke air-cooled CI engine developing 44 kW at 1500 rpm, was concluded that the power output and fuel consumption of the diesel engine was approximately the same when the engine was fuelled with lower poon oil-petro diesel blends compared with those of the conventional petro diesel. At full load, a 32% reduction in NOx emission for poon SVO and 4% reduction for its 20% blend was observed. The CO emissions from neat poon oil and its blends were higher as compared to the other blends. It was also observed that with 18% neat spoon oil HC emission increased, whereas it has been reduced to 14% reductions with neat 20% blend, They finally came to the conclusion that lower poon oil-petro diesel blends are potentially good substitute fuels for diesel engines.

Various methods have been taken into consideration for the reduction in viscosity of vegetable oils such as heating, dilution, micro emulsification, pyrolysis, catalytic cracking and transesterification. With the increase in temperature of the oil, its viscosity decreases. It is easier to pump lower viscosity biodiesel and atomize and achieve finer droplets. Furthermore, there were various problems that were discovered in long-term engine tests, which includes, coking on injectors, valve seats more carbon deposits, oil ring sticking, and thickening and gelling of the engine lubricant oil.

Various additives have been added to the conventional fuels for the improvement in efficiency and emission. Oxygenates like ethanol, i-butanol and i-pentanol reduced exhaust emissions and also improve the performance parameters.
1.1. What is Simarouba oil
Simarouba tree belongs to the Simaroubaceae Simarouba have compound leaves. Their flowers are unisexual and relatively small (1 cm long). The flowers of Simarouba are of 4 to 7.5 mm long, it has curved bright yellow with a touch of orange and red petals. Anthers are of 13 to 2mm long. Simarouba trees attain heights well up to 1000m. The temperature of the species suitable is about 10-50°C with an annual rainfall of about 500-2200 mm. Simarouba regenerates naturally through self-sown seeds that are disseminated through birds and other animals which feed on these fruits. Simarouba is also found very effective for cancer treatments.

1.2. What are Bio Fuels?
The variety of fuels which are acquired from crops and plants are known as biofuels. They are then blended with diesel and can be used as an alternative fuel for your car. Plant based fuels have various advantages, which includes that they come from renewable sources, they can be grown anywhere and have lower carbon emissions as compared to other fossil fuels. Biofuels also helps economy by providing job opportunities. It also contributes in reduction of greenhouse gases.
Since petroleum is a non-renewable source of energy and the petroleum reserves are running at an all time low, the main objective of the study is to conduct various performance and emission tests using Simarouba oil as the bio fuel and Isobutanol as the oxygenated additives and compare the results with the conventional fuel such as diesel in order to determine the best possible bio fuel blend that can be utilised as a viable conventional diesel alternative with improved emission characteristics.

2. Experimental Setup

2.1 Engine Test Setup
The experimental study was conducted on a naturally aspirated 4 stroke direct injection diesel engine with an eddy current type dynamometer which was attached to it that was used to apply load on the engine with an arm length of 0.185m thus providing a load over a range of 0kg to 18kg, having been used only to a maximum 16kg load. The engine has a constant running speed of 1500 RPM. The engine is manufactured by Kirloskar, which is fitted with a piezo type pressure sensor.

The values pertaining to emissions are acquired using an AVL Di-Gas 444 analyzer which provides with a reading of five exhaust gases namely CO₂, CO, NOx, HC and O₂.

The various bio fuel blends were formed by directly mixing the pure diesel with Simarouba oil and the additive Iso butanol. While undergoing this procedure, there was no need for any preheating of the mixture.

2.2 Fuels Used along with the various blends
The fuels used along with the various blends are given here.
1. Diesel  ---- Pure Diesel
2. Simarouba oil  ---- Raw Simarouba Oil
3. B40  ---- 60% Diesel (600 ml) + 40% Simarouba oil (400 ml)
4. \(B60\) \(---- 40\% \) Diesel \((400 \text{ ml}) + 60\% \) Simarouba oil \((600 \text{ ml})\)
5. \(B80\) \(---- 20\% \) Diesel \((200 \text{ ml}) + 80\% \) Simarouba oil \((800 \text{ ml})\)
6. \(B40+10 \text{ i-BUOH}\) \(---- 60\% \) Diesel \((600 \text{ ml}) + 40\% \) Simarouba oil \((400 \text{ ml}) - 100 \text{ ml} +100 \text{ ml} \text{ i-BUOH [1 litre]}\)
7. \(B60+10 \text{ i-BUOH}\) \(---- 40\% \) Diesel \((400 \text{ ml}) + 60\% \) Simarouba oil \((600 \text{ ml})- 100 \text{ ml} +100 \text{ ml} \text{ i-BUOH [1 litre]}\)
8. \(B80+10 \text{ i-BUOH}\) \(---- 20\% \) Diesel \((200 \text{ ml}) + 80\% \) Simarouba oil \((800 \text{ ml})-100 \text{ ml} + 100 \text{ ml} \text{ i-BUOH [1 litre]}\)

Where B stands for the Raw Simarouba oil and the no. corresponding to it represents its concentration in the respective blend whereas i-BUOH stands for the additive Isobutanol that was used in the tests.

2.3. Emission Measurement

The various exhaust gas parameters including the HC, CO\(_2\), NO\(_x\), O\(_2\) and CO emissions were also analysed. For the exhaust gas measurement, an AVL Di-Gas 444 analyser was used and the corresponding readings were noted.

3. Performance Graphs

3.1 Brake Thermal efficiency vs Brake Power

![Figure 3.1. Brake Thermal Efficiency vs Brake Power graph](image)

The Figure 3.1 depicts the graph between the brake thermal efficiency (BTE) and Brake power (BP) at a constant speed. It shows a linear relationship between the brake power and the BTE, i.e., the BTE enhances with an increase in the BP. Thus it was concluded that the BTE of the Simarouba blends B40% and B60% are the closest to the Diesel values under significantly larger loads.

It was also observed that the adding of the Simarouba oil decreases the value of the BTE and thus leading to the conclusion that the blends that are having higher Simarouba oil concentration, tend to possess lower value of BTE. The same trend is can be predicted for the addition of the additive (Isobutanol) which also tends to decrease the BTE.
3.2. Brake Specific Fuel Consumption (BSFC) vs Brake Power (BP)

Figure 3.2 is a graphical representation between BSFC and BP. The fuel consumption of the engine was analysed from the volume flow rate and density, taking into account that the engine is running at a constant speed. It can clearly be seen that with the increase in BP, there was a decrease in BSFC, resulting to an inverse trend of the BTE vs BP graph. It was also observed that as the amount of Simarouba Oil increases in the bio fuel blends, the BSFC also increases. Blend B40 comes closest to the diesel.

4. Emission Graphs

4.1. Carbon Dioxide (CO$_2$) vs Load Applied

Figure 4.1 is a graphical representation between CO$_2$ and the load applied. The CO$_2$ emissions were measured for different blends of biofuels and diesel. It can be observed that as the load increases, the CO$_2$ emissions also increase. Blend B40, which is a blend of 60% diesel and 40% Simarouba Oil, shows the lowest CO$_2$ emissions compared to other blends.
The Figure 4.1 shows that B80+10% has always attained the highest values in the curve whereas the blends, B40, B40+10% have the lowest values in the graphs.

Note: For a proper combustion process to take place, the value of the carbon dioxide (CO₂) should be high.

4.2 Carbon Monoxide (CO) vs Load Applied

It can be clearly seen from Figure 4.2 that the value of CO is lower for B40 blend as compared to diesel. It was also seen that with the rise in the amount of Isobutanol in the biofuel blends, the Carbon Monoxide (CO) emissions decreases.

4.3 Smoke vs Load Applied

Figure 4.2 Carbon Monoxide vs Load Applied graph

Figure 4.3 Smoke vs Load Applied graph
As depicted in Figure 4.3, the lowest value of smoke is for B40 blend and highest is for the B60+10% and B80 blend.

4.4 Hydrocarbon (HC) vs Load Applied

As can be seen from Figure 4.4, the values of Hydrocarbon (HC) for the B60 and B80 blends are greater than those of the other blends. With the addition of Simarouba oil, it was deduced that the HC values increases which in turn results to higher HC values for B60 & B80 blends.

4.5 Nitrogen Oxide (NOx) vs Load Applied

Figure 4.4. Hydrocarbon vs Load applied graph

Figure 4.5. Nitrogen Oxide vs Load Applied graph
The figure 4.5 depicts the various parameters of a proper designated NOx curve that are rising with load. Thus with an increase in the temperature of the cylinder, the amount of NOx produced also increases. It also rises with the rise in the load applied.

5. Conclusion

The different characteristics pertaining to the engine performance as well as emissions were analysed experimentally on a 4 stroke diesel engine running at a constant speed of 1500 RPM. These tests were carried out with varying of the load for the different bio fuel blends of Simarouba oil and Isobutanol with diesel which were prepared on volume basis, namely, B40, B60, B80, B40+10, B60+10, B80+10. The effects were observed at different Brake power and the subsequent deductions were made.

1) With the incorporation of Simarouba Oil in diesel, it was observed that the density and viscosity of the fuel increased along with a decrease in its calorific value.
2) Also, addition of Isobutanol to diesel blended with Simarouba oil increases its density, calorific value and viscosity.
3) With an increase in the concentration of Simarouba Oil in the blend, the BTE of the fuel kept on decreasing along with an increase in its BSFC.
4) Due to increase in the values of CO, CO₂, NOx and Smoke with addition of Simarouba oil in the blends, the overall emissions were also likely to be increased. It was also observed that the characteristics of combustion tend to be better at lower loads but were found out to be similar at higher loads.
5) Study indicates that simarouba oil and the additive Isobutanol have the potential to be used as fuel additive, concluding with B40 Isobutanol% blend being the best suited blend that can be utilised in lieu of pure conventional diesel.

6. Scope of Future Work

Experimental test conducted using Simarouba oil and the additive Isobutanol solvent along pure diesel on various proportions as an alternate fuel to meet the stringent demand of resources and to reduce the emissions. By testing with various blends the conclusion was made pertaining to B40 Isobutanol% blend being the best suited blend that can be utilised in lieu of pure conventional diesel. For future enhancement of this investigation of B40 blend, the emissions need to be further reduced and thus prove to be as a cost effective alternative fuel.

References

[1] Mishra S. R., Mohanty M. K., Das S. P. and Pattanaik A. K., “Production of Biodiesel (Methyl Ester) from Sinaroutu Glauca oil”, Research Journal of Chemical Sciences, Vol.2(5), pp.66-71, 2012.
[2] Vishwanath Kasturi and M.C. Navindgi, "An Experimental Analysis of Performance, Combustion and Emission Characteristics of Simarouba Biodiesel and Its Blends on CI Engine", International Journal of Modern Engineering Research (IJMER), Vol 4(8), pp. 63-69, 2014
[3] Harish Astagi, Shailesh Golabhanvi, Omprakash Hebbal, “Performance Emission and Combustion Characteristic of a Single cylinder Diesel engine operating on Simarouba biodiesel and diesel oil ”, International Journal of Emerging Trends in Engineering and Development, Vol.3, pp. 201-213, 2014
[4] M.C. Navindgi, and Vishwanath Kasturi, “Experimental Investigation of Performance and Emission Characteristics of Simarouba Biofuel and Its Blends on LHR Engine”, International Journal on Modern Engineering Research (IJMER), Vol. 4, pp.63-69, 2014
[5] Sharun Mendonca, and John Paul Vas, "Influence of Injection Timing on Performance and Emission Characteristics of Simarouba Biodiesel Engine", International Journal of Scientific and Research Publications, Vol. 3(4), pp. 1-6, 2013.
[6] V. V. Katti, Dilip Sutraway, and, Y. U. Biradar, “To find the Effect of Performance of Fuel Injection Time in compressed ignition Engine Using (Simarouba) as Biofuel”, Journal of Mechanical Engg Research and Technology, Vol.2, pp.556-572, 2014.
[7] Anand Srinivasa.C and Saravanan CG, "Study of Combustion Characteristics of a SI Engine Fuelled with Ethanol and Oxygenated Additives", Journal of Sustainable Energy & Environment, Vol. 1, pp.85-91, 2010.

[8] Barsic, N. and Humke, A., "Performance and Emissions Characteristics of a Naturally Aspirated Diesel Engine with vegetable Oil Fuels," SAE Technical Paper 810262, 1981, https://doi.org/10.4271/810262.

[9] Venkatesan, Balaji D. and Govindarajan P., "Influence of Isobutanol blend in SI engine, the Performance and emissions operated with gasoline and Ethanol", International Journal of Engineering Science and Technology, Vol. 2(7), pp.2859-2868, 2010.

[10] Bajpai S., Sahoo P.K., Das L.M., "Feasibility of Blending Karanja Vegetable Oil in Petro-diesel and Utilization in a Direct Injection Diesel Engine", Fuel, Vol. 88, pp. 705-711, 2009.

[11] C.S.Koli, Ram Bansal, Amit Agrawal, Ashish Agrawal, “Experimental Investigation of performance of single cylinder 4 stroke Diesel engine Using Dual Vegetable Oil Blended”, International Journal of Engineering Research and Applications, Vol. 4(3), pp. 78 – 85, 2014.

[12] Mahalakshmi N.V. and Devan P.K., "Performance, Emission and Combustion Characteristics of Poon Oil and its Diesel Blends in a Direct Injection Diesel Engine", Fuel, Vol. 88(5) pp.861-867, 2009.