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Extraction of Simarouba Biodiesel and Experimental Investigation of its Suitability as Fuel for CI Engine

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Abstract:
Bio-diesel is one of the most promising alternatives for diesel needs. Use of edible oils may create shortage of oil for daily food. This required identification of new kinds of non-edible vegetable oil. With this objective, the present work has focused on the performance, combustion and emission characteristics of diesel engine using simarouba oil and its blends with diesel. In this investigation, the blends of varying proportions of simarouba biodiesel with diesel (S20, S40, S60, S80 & S100) were prepared, analyzed, and compared the performance and exhaust emission with diesel using 5.2 kW Single cylinder, 4stroke diesel engine. The performance and emission characteristics of blends are evaluated at variable loads and constant rated speed of 1500 rpm and found that the performance of S20 blend of simarouba oil gives result, that is near to the diesel and also found that the emission CO, CO_2, HC, smoke & NO_X of this blend is less than the diesel.

Keywords: *Biodiesel, Simarauba, Alternate fuel, CI Engine*

1. Introduction

According to the present scenario diesel engines are commonly used as prime movers in the transportation, industrial and agricultural sectors because of their high brake thermal efficiency and reliability. Energy conservation and efficiency have always been the quest of engineers concerned with internal combustion engines.

In this work, we have adopted Simarauba glauca oil. S*imarouba glauca* belongs to family simarubaceae.

2. Materials and Methods

The extraction of biodiesel is carried out by base catalyzed transesterification method.

2.1. Process of Extracting

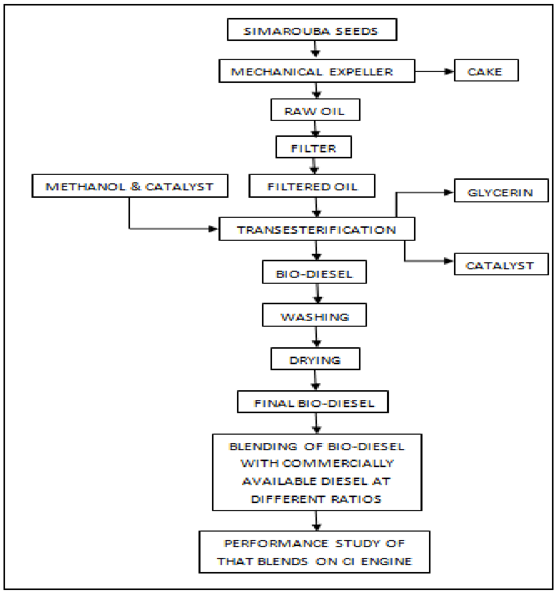
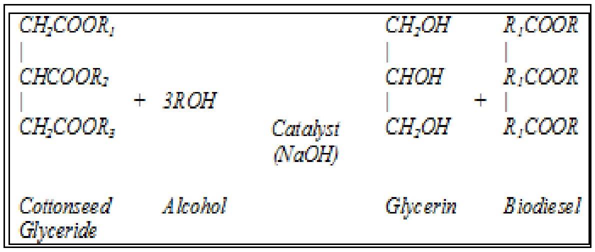


Figure 1: The flow chart for biodiesel production

To a one liter of raw Simarauba oil is heated up to 70 ^{0}C. 300 ml of methanol & 5-7gms of NaoH (catalyst) is added and the mixture is maintained at 65-70 ^{0}C is about 1½ hours and stirred continuously. The mixture is allowed to settle for 20-30 min until the formation of biodiesel and glycerin layers. The glycerin is removed from the bio-diesel in a separating funnel. The bio diesel produced from Simarouba oil is ready to use.

2.2. Transesterification

It is most commonly used and important method to reduce the viscosity of vegetable oils. In this process triglyceride reacts with three molecules of alcohol in the presence of a catalyst producing a mixture of fatty acids, alkyl ester and glycerol. The process of removal of all the glycerol and the fatty acids from the vegetable oil in the presence of a catalyst is called esterification.



$$\begin{matrix} CH_2COOR_1 \\ | \\ CHCOOR_2 \\ | \\ CH_2COOR_3 \end{matrix} + 3ROH \xrightarrow[(NaOH)]{Catalyst} \begin{matrix} CH_2OH \\ | \\ CHOH \\ | \\ CH_2OH \end{matrix} + \begin{matrix} R_1COOR \\ | \\ R_1COOR \\ | \\ R_1COOR \end{matrix}$$

Chemical reaction

Physical and chemical properties are more improved in esterified vegetable oil because esterified vegetable oil contains more cetane number than diesel fuel. These parameters induce good combustion characteristics in vegetable oil esters. So unburnt hydrocarbon level is decreased in the exhaust. It results in lower generation of hydrocarbon and carbon monoxide in the exhaust than diesel fuel. The vegetable oil esters contain more oxygen and lower calorific value than diesel. So, it enhances the combustion process and generates lower nitric oxide formation in the exhaust than diesel fuel.

3. Properties of Diesel and Some Blends

After transesterification the properties of Simaruba oil blends was determined. It was found that the properties of Simaruba oil blends were similar to diesel.

Properties	Diesel	S20	S40	S100
Kinematic viscosity at 40^0C (Cst)	2.54	3.104	3.891	5.6
Calorific value (kJ/Kg)	42500	42270	41949	37933
Density (kg/m^3)	840	838	846	875
Flash Point (^{o}C)	54	79	98	165
Fire Point (^{o}C)	64	89	110	185

Table 1: Properties of Simaruba oil blends

4. Experimental Setup

The experimental setup enables study performance, combustion and emission characteristics. The experiments have been carried out on a DI compression ignition engine for various blends of simarouba oil with diesel (S20, S40, S60, S80, and S100) with varying brake power. The experiment is carried out at constant compression ratio of 17.5:1 and constant injection pressure pressure of 200 bar by varying brake power.

Figure 2: Photograph of engine setup

Manufacturer	Kirloskar oil engines Ltd, India
Model	TV-SR, naturally aspirated
Engine	Single cylinder, DI
Bore/stroke	87.5mm/110mm
Compression Ratio	17.5:1
speed	1500r/min, constant
Rated power	5.2kw
Working cycle	4 stroke
Injection pressure	200bar/23 def TDC
Type of sensor	Piezo electric
Response time	4 micro seconds

Table 2: Engine specifications

5. Result and Discussion

5.1. Performance Characteristics

- **Brake thermal efficiency:** The fig 3 shows the variation of brake thermal efficiency with brake power output for various blends of diesel and simarauba oil. For all the cases, with the increase of engine load, the thermal efficiency increases. The BTE of the Simarauba blends was lower than that of diesel for the entire range of operation. The BTE of 20% blend of simarauba oil compared with diesel exhibits the highest value at 26.75% of total load obtained at 4.06 kw against the 26.88% of diesel. The drop in thermal efficiency is attributed to the poor combustion characteristics of the vegetable oils due to their high viscosity and poor volatility.
- **Brake specific fuel Consumption:** The variation of brake specific fuel consumption with brake power output for simarauba oil and its blends with diesel in the test engine are shown in the figure 4. Diesel has lower bsfc compared to all other blends; however 20% blend of simarauba oil has lower SFC values. The increase in bsfc of Simarauba oil and their blends may be due to their lower calorific value. For the fuels tested, brake specific fuel consumption decreased with increase in load. One possible explanation for this reduction could be due to higher percentage of increase in brake power with load.

- **Brake specific energy consumption:** The brake specific fuel consumption is not a very reliable parameter to compare the two fuels as the calorific value and density of the blend follow a slightly different trend. Hence, brake specific energy consumption is a more reliable parameter for comparison. Figure 5 shows the comparison of brake specific energy consumption with brake power for diesel, simarouba and its blends. Brake specific energy consumption of methyl ester of simarouba oil for entire range of operation is comparable to that of diesel. At rated load brake specific energy consumption of methyl ester of simarouba oil is found 40% lower than that of diesel. Energy based fuel economy of engine is better than that of diesel.
- **Exhaust gas temperature:** Fig 6 shows the variation of exhaust gas temperature (E.G.T) with brake power output for simarouba oil and its blends with diesel in the test engine. The EGT of all blends and diesel increase with increase of operating loads. This is an indication of lower exhaust loss and could be possible reason for higher performance.

5.2. Emission Characteristics

- **Carbon monoxide:** Fig 7 shows the comparison of brake power with carbon monoxide for different biodiesel blends. The CO emission depends upon the strength of the mixture, availability of oxygen and viscosity of fuel. It is observed that the CO emission initially decreases at lower loads sharply increases after 4 kW of power for all test fuels. And the diesel and simarouba oil with 80%blend has more emission of CO compared with blends of simarouba oil like S20, S40, S60 and S100. This due to incomplete combustion at higher loads which results in higher CO emissions. It is also seen that the CO Emission decreases with increase in percentage of additive in the blends. From this graph it is revealed that S100 (pure simarouba oil) shows lowest carbon monoxide emission compare to all other test fuels up to 4kw of power and then increases due to incomplete combustion.
- **Unburnt hydrocarbon:** Figure 8 shows the variation of emission of hydrocarbon with brake power for different blends of simarouba biodiesel and pure diesel. The emission of HC is decreasing with increase of loads. It can be confirmed that both conventional diesel and biodiesel had the same functional group of C–H. However, the conventional diesel had no oxygen group, whereas biodiesel showed oxygen functional group. Therefore, the biodiesel with the existence of oxygen could be promoted cleaner and complete combustion. On the other hand, the conventional diesel without any oxygen produced more black smoke and incomplete combustion during burning.
- **Smoke:** The variation of emission of smoke (%) with brake power for diesel and different blends of biodiesel oils are shown in figure 9. The biodiesel blend produced less black smoke compared to the conventional diesel due to the oxygen content. Moreover, the incomplete combustion of hydrocarbon will produce black smoke too. Thus, the conventional diesel is an incomplete combustion but when it is mixed with biodiesel, the combustion produced is more complete. A complete combustion was obtained with higher biodiesel blend. Hence, the biodiesel blend is much more environmentally friendly compared to the conventional diesel.
- **Oxides of nitrogen:** The fig 10 shows that the NO_x emission increased with the increase concentration of biodiesel. NO_x emission is primarily a function of total oxygen inside the combustion chamber, temperature, pressure, compressibility, and velocity of sound. Invariably biodiesel has S level of oxygen bound to its chemical structures. Thus, oxygen concentration in biodiesel blends fuel might have caused the formation of NO_x. Furthermore, the increase of NO_x emission is due to the higher cetane number of biodiesel which will reduce the ignition delay. The increase of NO_x emission is a result of the reduced ignition delay. However, the NO_x emissions can be reduced through engine tuning or using exhaust catalytic converter. At any rate, the NO_x still can be reduced with the advanced technologies such as catalytic converter, EGR and engine tuning.

5.3. Combustion Characteristics

- **Cylinder pressure:** Variation of cylinder pressure with crank angle at maximum load for S20, S40, S60, S80, and S100 is shown in figure 11. The fraction of fuel burnt during the premixed burning phase decides the cylinder pressure. Vegetable oils have higher cetane number. This shortens the ignition delay period. This results in reduction in fuel injection, maximum pressure and temperature when compared with those of diesel. The trend is of S100 is however is same as that of D100 pressure diagram. The cylinder peak pressure is found highest with D100 followed by S100. From the observation it was noted that the occurrence of pressure moves away for S100 compared to D100. This shows that S100 has longer ignition delay compared to D100. This is because of low cetane number of S100. Due to poor volatility, high viscosity, lower heating value and poor spray characteristics of S100 leads to less fuel being prepared for rapid combustion.
- **Net heat release rate:** Fig 12 shows the variation of net heat release rate with respect to crank angle. In diesel, premixed burning is more pronounced. S100 shows lower heat release rate compared to D100 during premixed burning phase. The poor atomization and poor fuel-air mixing is attributed to high viscosity and poor volatility of vegetable oils. This consequently leads to higher exhaust gas temperature and loss of power because burning occurs in diffusion phase.
- **Cumulative heat release:** Variation of cumulative heat release with crank angle is shown in figure 13. D100 and S100 reveal rapid premixed fuel burning occurs followed by diffusion combustion. Once the ignition delay period is passed, the premixed fuel air mixture burns very fast, releasing the heat very rapidly and then diffusion combustion takes place. During the latter it is possible to control the burning rate by regulating the quantity of available air-fuel mixture.

  From forgoing discussions it can be stated that smoke, CO, un-burnt HC and exhaust temperature of S100 are lower than that of diesel, which indicates that in early stage of exhaust stroke effective combustion of S100 is taking place. This is due to reduction in viscosity of S100. Increases the volatility, decrease in flash point improves the spray formation which contributes for effective combustion. Reduction in brake specific fuel consumption, increases in brake thermal efficiency and brake specific energy consumption reflect to a reduced emission.

6. Conclusion

The properties of Simarauba and its blends were analyzed. High viscosity and cloud point makes the simarauba not compatible to be used raw in the engine and hence justifies the need for transesterification. The high catalytic activity, re-usability, lower emission rates, improved engine performance and makes it a promising candidate when compared with conventional catalysts.

As can be observed S20 is the most suitable biodiesel blend among all. The first criterion is that the engine power output of S20 is not much different from conventional biodiesel. Secondly, the specific fuel consumption of S20 is much lower than the S40 and S60. In this criterion, S20 is selected, as the SFC is slightly the same with Diesel, and the higher biodiesel blend produces better combustion. Lastly, the S20 has lower average percentage of change in CO_2, CO, and HC compared to Diesel. Yet, S20 is producing higher NOx emission. Nevertheless, the S20 is still the suitable biodiesel blend amongst all as the NOx emission can be reduced with the advanced technologies.

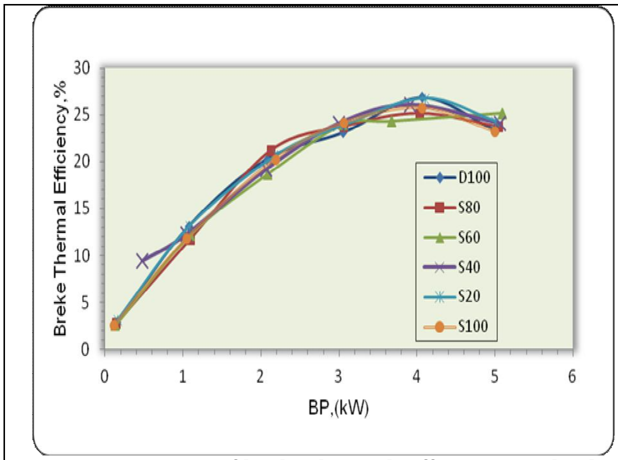


Fig. 3 Variation of brake thermal efficiency v/s brake power

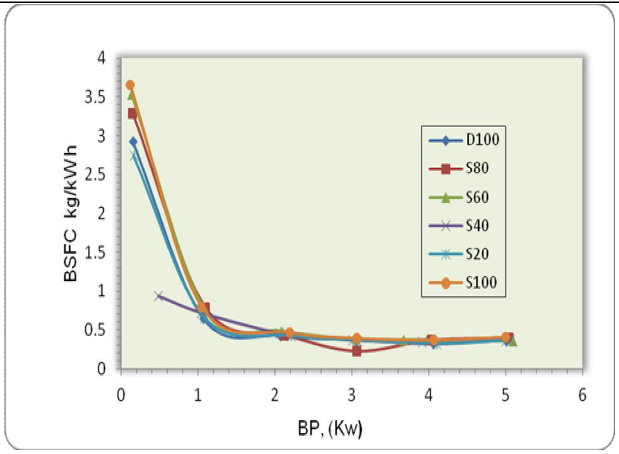


Fig 4 Variation of bsfc with brake power

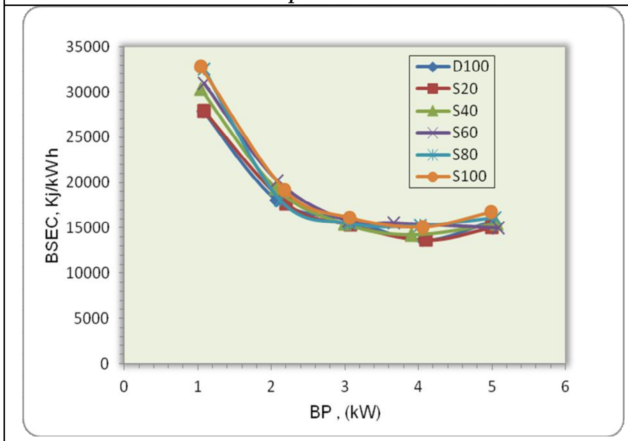


Fig 5 Variation of BSEC with brake power

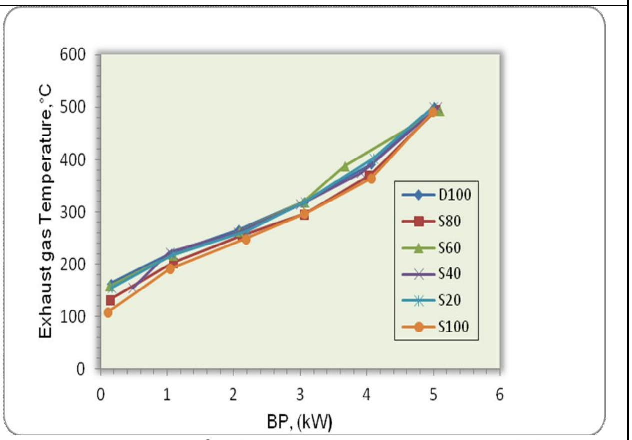


Fig 6 Variation of exhaust gas temperature with brake power

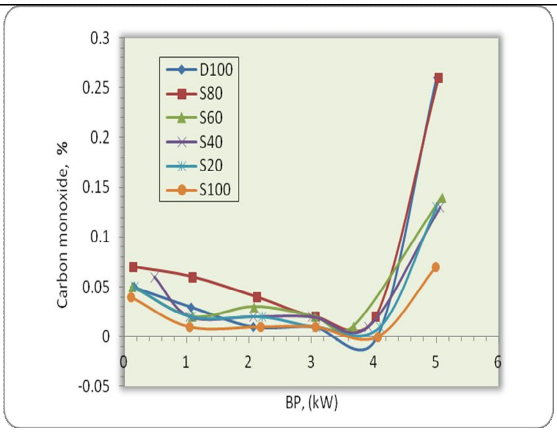


Fig 7: The variation of carbon monoxide with brake power

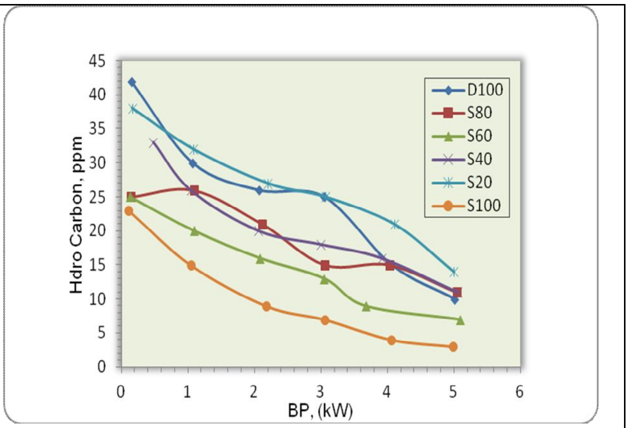


Fig 8: The variation of un burnt hydrocarbon with brake power

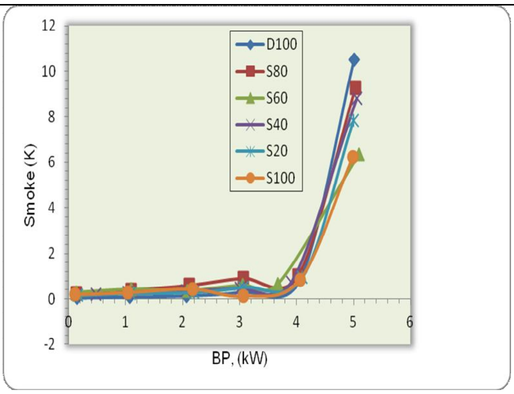


Fig 9: The variation of smoke emission with brake power

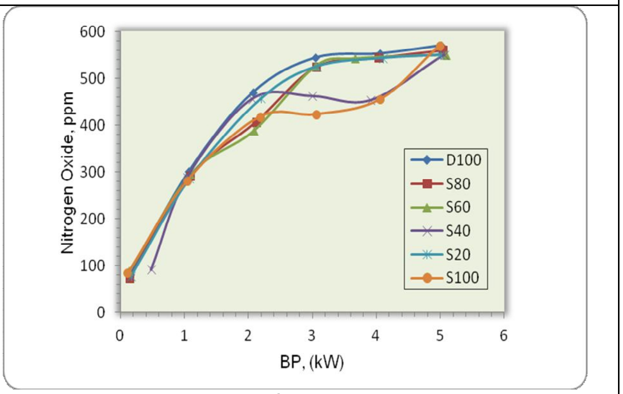


Fig 10: The variation of smoke emission with brake power

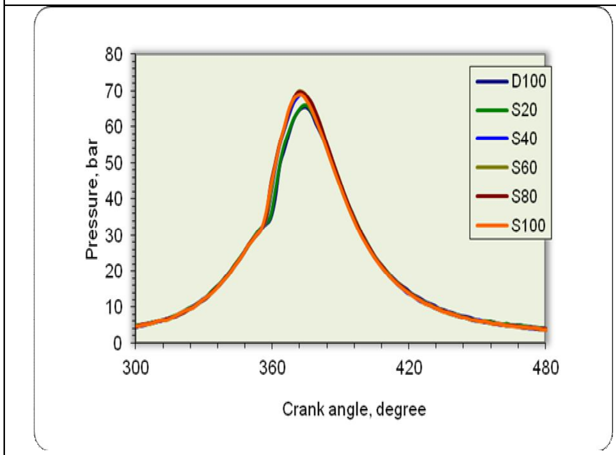


Fig.11: The variation of cumulative heat release with crank angle

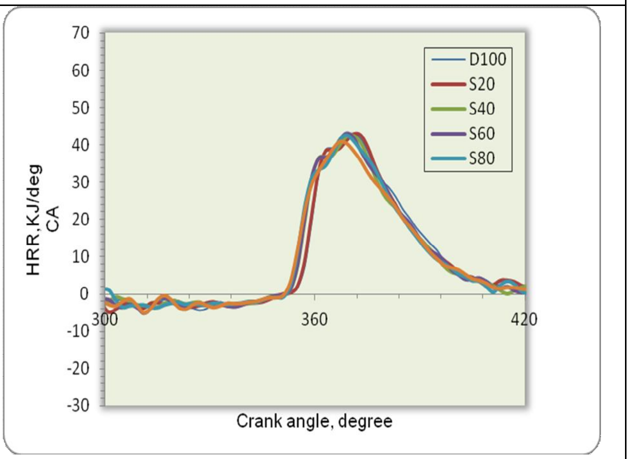


Fig.12: The variation of heat release rate with crank angle

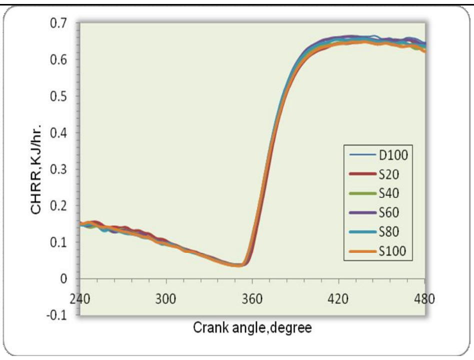


Fig.13: Variation of cumulative heat release with crank angle

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