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An Experimental Analysis of Performance, Combustion and Emission Characteristics of Simarouba Biodiesel and Its Blends on 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, combustion and exhaust emission with diesel using 5.2 kW Single cylinder, 4stroke diesel engine. The performance, combustion 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, HC, & NO_X of this blend is less than the diesel.*

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

I. 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.

II. Materials And Methods

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

2.1. Process of Extracting

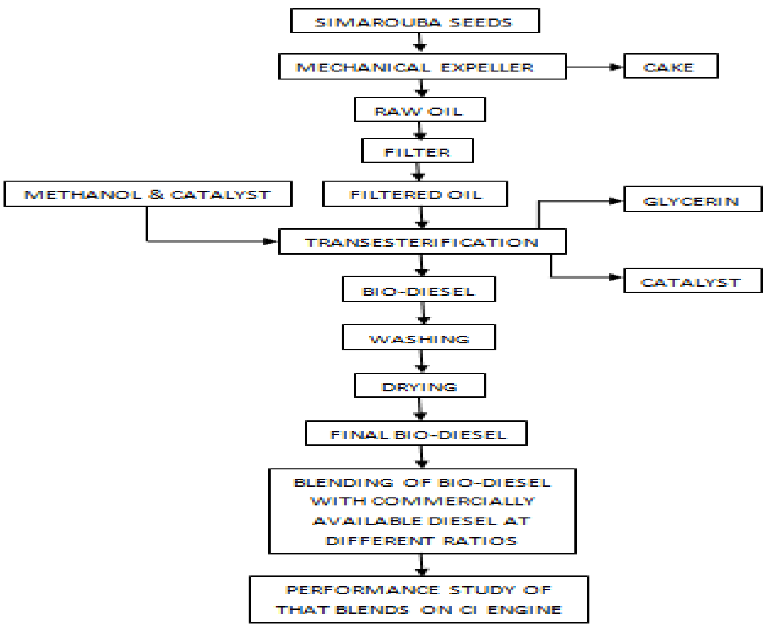

Fig 2.1: The flow chart for biodiesel production

To a one liter of raw Simaroauba oil is heated up to 70^0C. 300 ml of methanol & 5-7gms of NaOH (catalyst) is added and the mixture is maintained at 65-70^0C 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.

CH2COOR1				CH2OH		R1COOR
|				|		|
CHCOOR2				CHOH		R1COOR
|	+	3ROH	⟷	|	+	|
CH2COOR3			Catalyst (NaOH)	CH2OH		R1COOR
Cottonseed Glyceride		Alcohol		Glycerin		Biodiesel

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.

III. Properties Of Diesel And Some Blends

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

Table 3.1: Properties of Simarouba oil blends

Properties	Diesel	S20	S40	S100
Kinematic viscosity at 400C (Cst)	2.54	3.104	3.891	5.6
Calorific value (kJ/Kg)	42500	42270	41949	37933
Density (kg/m3)	840	838	846	875
Flash Point (^{0}C)	54	79	98	165
Fire Point (^{0}C)	64	89	110	185

IV. 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 of 200 bar by varying brake power.

Fig 4.1: Photograph of engine setup

Table 4.1: Engine specifications

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

V. Result And Discussion

5.1 Performance characteristics

5.1.1 Specific fuel consumption

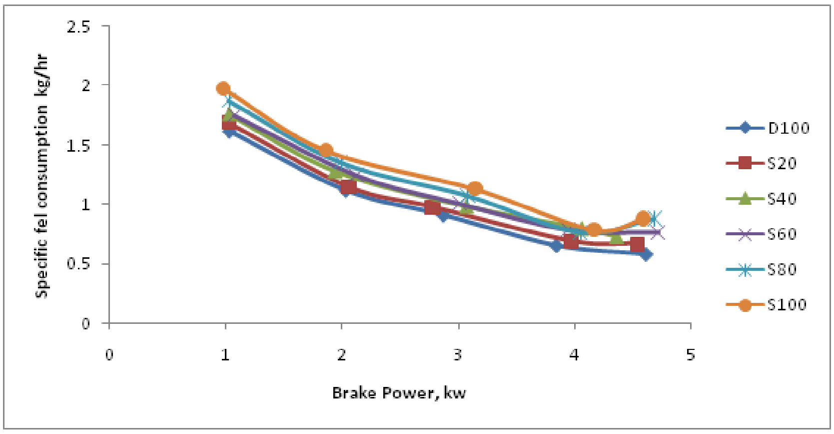

Fig 5.1 The variation of the specific fuel consumption with brake power for diesel and simarouba blends

The variation of specific fuel consumption with brake power for diesel, and simarouba biodiesel oil and it's blend are shown in figure 5.1. Specific fuel consumption for simarouba biodiesel blends are higher than diesel for certain lower loads, but for higher loads, consumption rate remains almost constant as evident from the graph. This may be due to fuel density, viscosity and heating value of the fuels. The main reason for this could be that percent increase in fuel required to operate the engine is less than the percent increase in brake power due to relatively less portion of the heat losses at higher loads.

5.1.2 Air fuel ratio

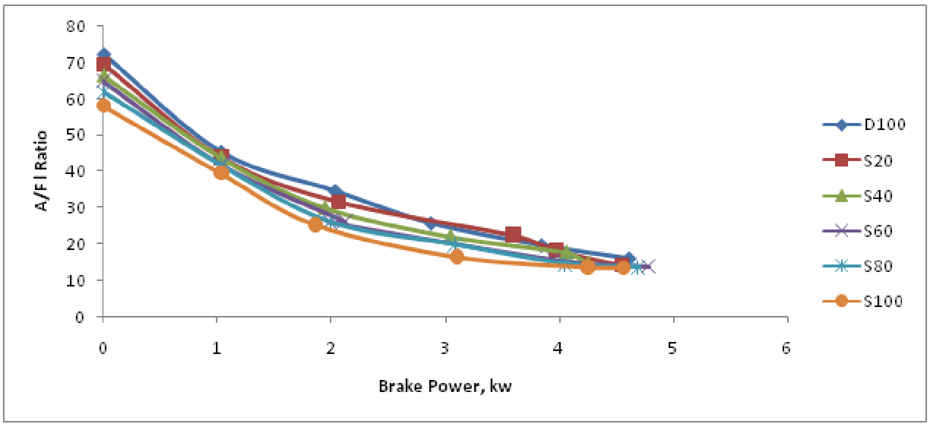

Fig 5. 2 The variation of the air fuel ratio with brake power for diesel and simarouba blends

The variation of air fuel ratio with brake power for diesel and simarouba biodiesel blends are shown in figure 5.2. It can be observed that air fuel ratio of pure diesel is higher than other simarouba biodiesel and its blends, and we can also see that the air fuel ratio decreases as the load increases. Because the reason is air fuel ratio decreases due to increase in load because of the compensation of load can only be done with increasing the quantity of fuel injection to develop the power required to bare the load.

5.1.3 Brake thermal efficiency

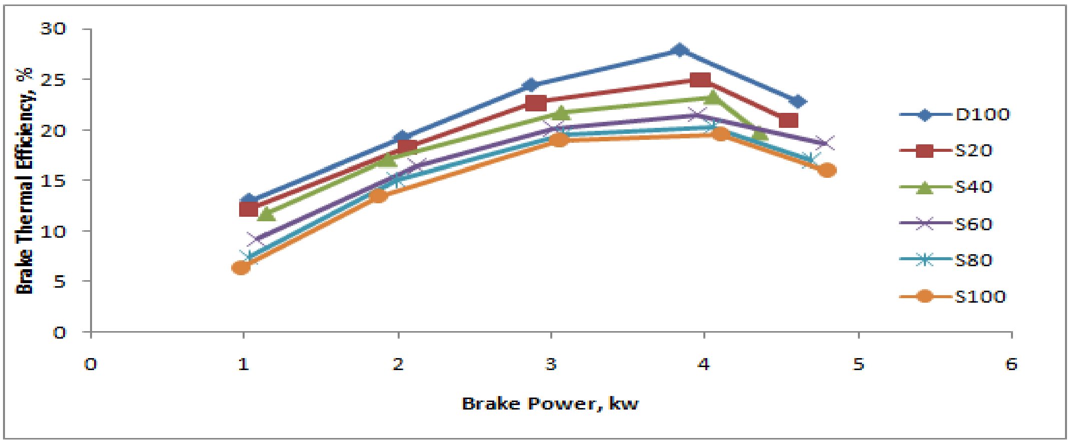

Fig 5. 3 The variation of the brake thermal efficiency with brake power for diesel and simarouba blends

The variation of brake thermal efficiency with brake power for diesel, and simarouba biodiesel and its blend are shown in figure 5. 3. shows the break thermal efficiency of simarouba biodiesel and its blends with respect to brake power. It shows that brake thermal efficiencies of all the blends are lower at almost all load levels. Among the blends S20 is found to have the maximum thermal efficiency of 25.01% at a brake power of 3.97 kW while for diesel it is 27.84%. The decrease in brake thermal efficiency with increase in simarouba biodiesel concentration is due to the poor atomization of the blends due to their high viscosity and reduction in heat loss and increase in power with increase in load.

5.1.4 Exhaust gas emission

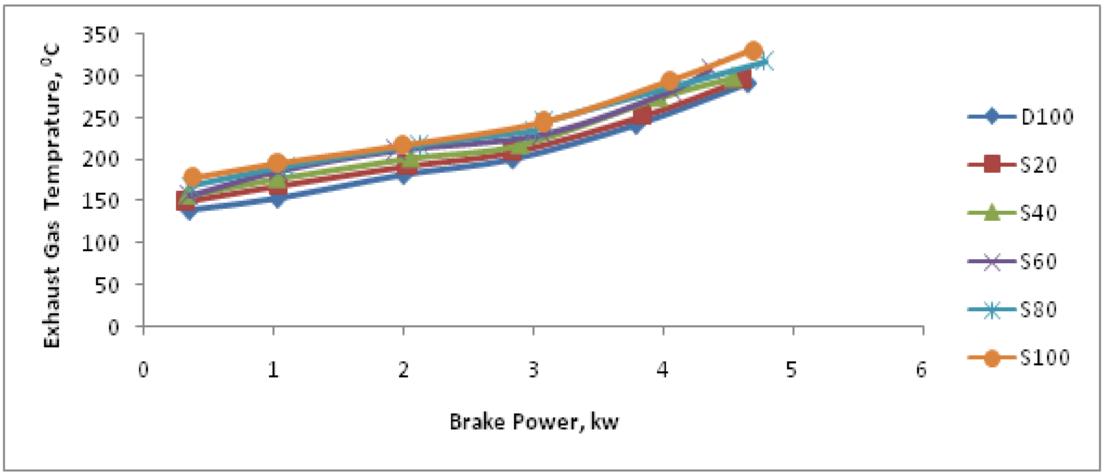

Fig 5.4 The variation of the exhaust gas temperature with brake power for diesel and simarouba blends

The comparisons of exhaust emission temperature with brake power for diesel, and other blends of simarouba biodiesel are shown in figure 5.4 the exhaust emission temperature of all the biodiesel are higher than the diesel as it is evident from the graph. The exhaust gas temperatures for 100% diesel and 20%, 40%, 60%, 80%, 100% blends for varying loads can be observed and stated as they are slightly parallel to each other. The exhaust gas temperature of all the blends and 100% diesel increase as the load increases. It is observed that, at full load the exhaust gas temperature is maximum, this is because; at full load the chemically correct ratio of air and fuel is used, due to chemically correct ratio of air and fuel, high heat is generated inside the cylinder.

5.2 Emission characteristics
5.2.1 Carbon monoxide

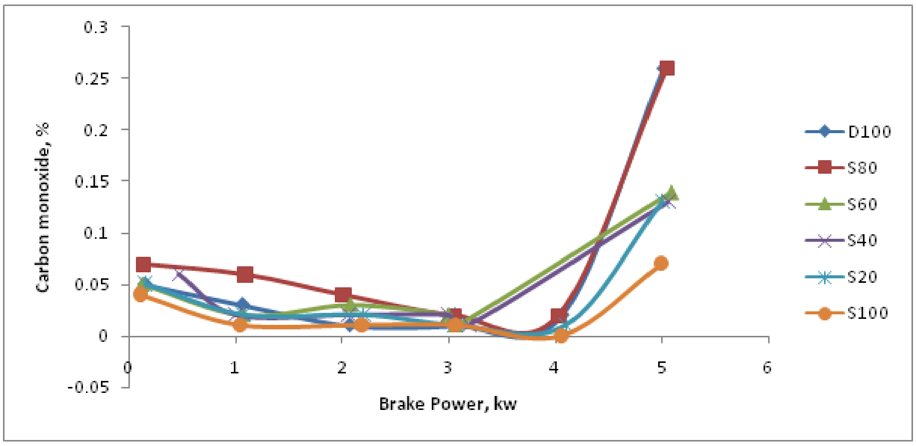

Fig 5.5 The variation of the carbon monoxide with brake power for diesel and simarouba blends

Fig 5.5 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. Because the reason is high viscosity and small increase in specific gravity suppresses the complete combustion process, which produces small amount of CO.

5.2.2 Hydro carbon

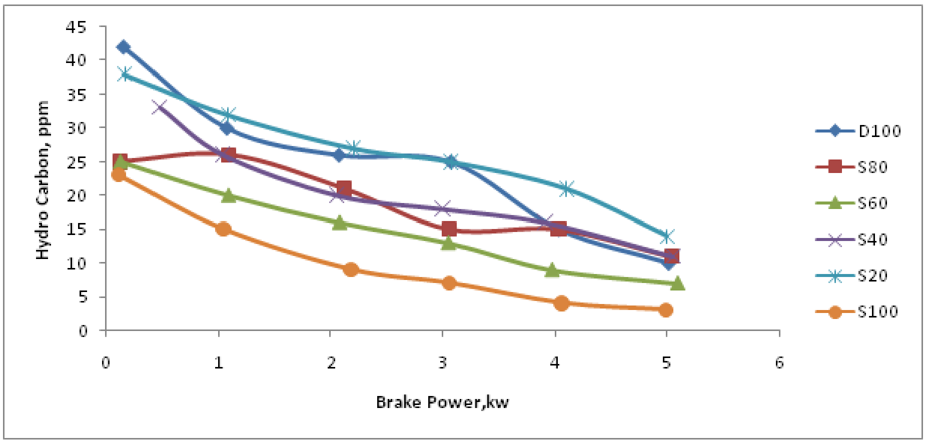

Fig 5.6 The variation of the hydro carbon with brake power for diesel and semarouba blends

Figure 5.6 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, but the blend S20 exhibits emission of HC similar to diesel. And we observe that the S100 has the least emission of HC compared to other blends. Thus, 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. Because the reason is as the Catani number of ester based fuel is higher than diesel, it exhibits ashorter delay period and results in better combustion leading to low HC emission. Also the intrinsic oxygen contained by the biodiesel was responsible for the reduction in HC emission.

5.2.3 Nitrogen oxide

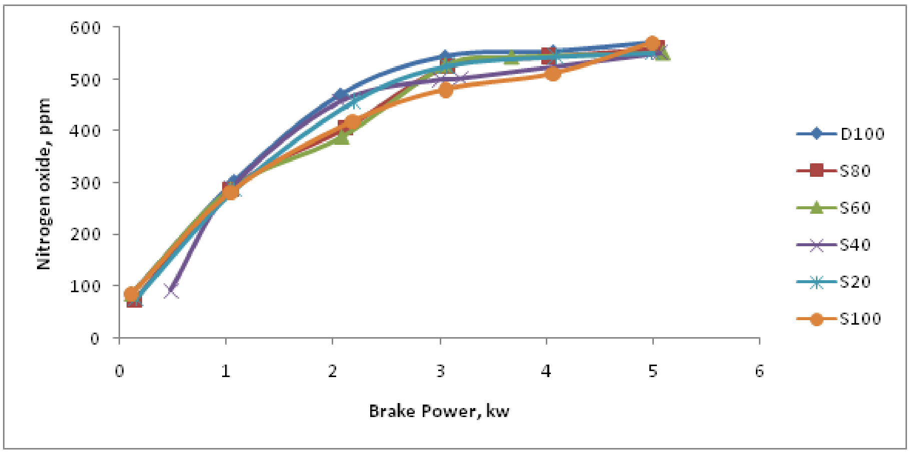

Fig 5.7 The variation of the nitrogen oxide with brake power for diesel and semarouba blends

The average percentage of change in NOx emission for S20, S40, S60, S80, and S100 are shown in the graph. This shows that the NOx emission increased with the increase of percentage ratio of biodiesel. NOx emission is primarily a function of total oxygen inside the combustion chamber, temperature, pressure, compressibility, and velocity of sound. Invariably biodiesel has S20 level of oxygen bound to its chemical structures. Thus, oxygen concentration in biodiesel blends fuel might have caused the formation of NOx . Furthermore, the increase of NOx emission is due to the higher cetane number of biodiesel which will reduce the ignition delay. The increase of NOx emission is a result of the reduced ignition delay. However, the NOx emissions can be reduced through engine tuning or using exhaust catalytic converter. At any rate, the NOx still can be reduced with the advanced technologies such as catalytic converter, EGR and engine tuning.

The NOx emission for biodiesel and its blends is higher than that of diesel except S20 at lower loads. It is increased with the increase in engine load. The maximum NOX values were obtained at full load conditions and were 570, 560,550,550,550,570 ppm with respect t0 D100, S80, S60, S40, S20, S100.The reason for higher NOx emission for blends is due to the higher peak temperature and the biodiesel had S oxygen content in it, which facilated NO_X formation.

5.3 Combustion Characteristics

5.3.1 Variation of crank angle versus cylinder pressure

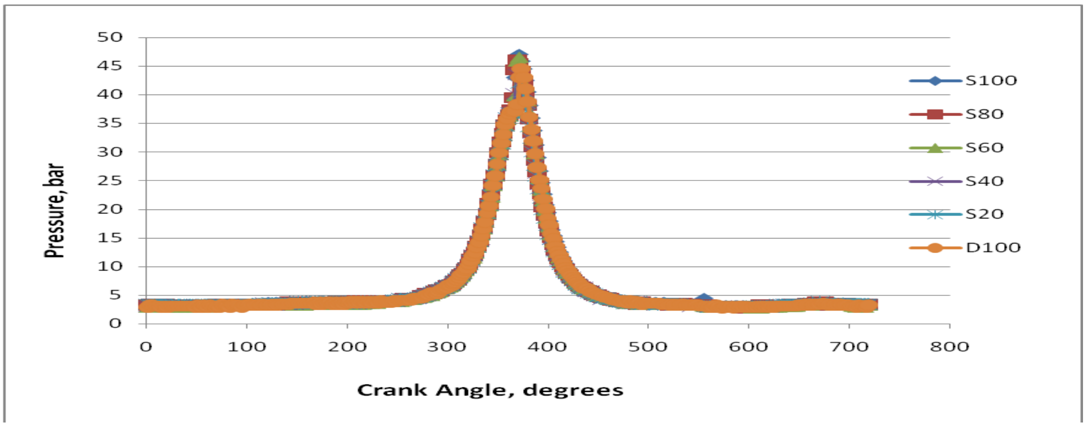

Fig 5.8 Variation of crank angle versus cylinder pressure

In a CI engine the cylinder pressure is depends on the fuel-burning rate during the premixed burning phase, which in turn leads better combustion and heat release. The variation of cylinder pressure with respective crange angle for diesel and different blends of simarouba biodiesel are presented in fig 5.8 peak pressure of 44.54bar and 43.69bar are found for puer diesel and S40 respectively. From the test results it is observed that the peak presure variations are less since the properties such as calorific value, viscosity and density are brought closer to diesel after transestirification of vagitable oil, no magare variation in the pressure are found.

5.3.2 Variation of crank angle versus heat release rate

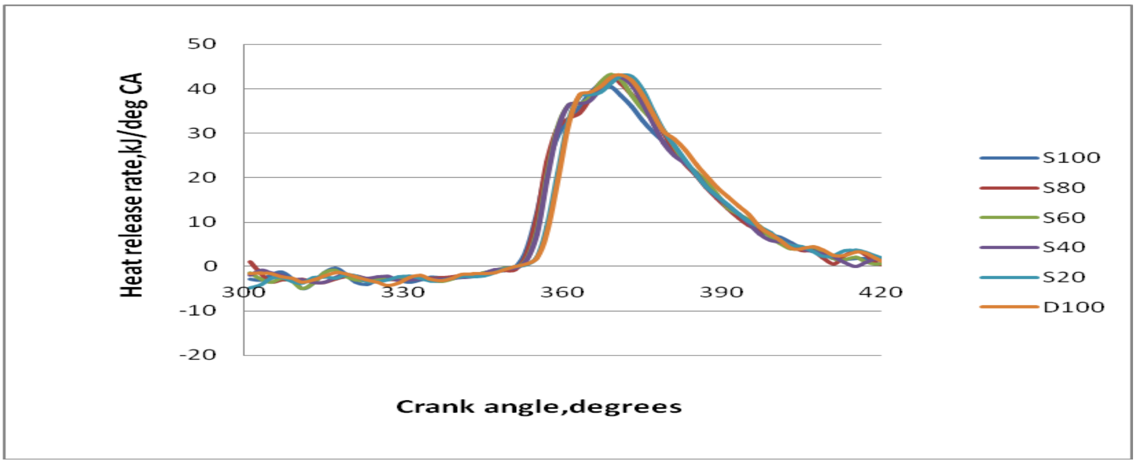

Fig 5.9 Variation of crank angle versus heat release rate

The fig-5.9 shows that the variation of the heat release rate with crank angle.It is observed that all theblends of simarouba oil traces the path of pure diesel and S60 are 43,11044kj and 43,2087kj at 3710.

5.3.3 Variation of crank angle versus cumulative heat release rate

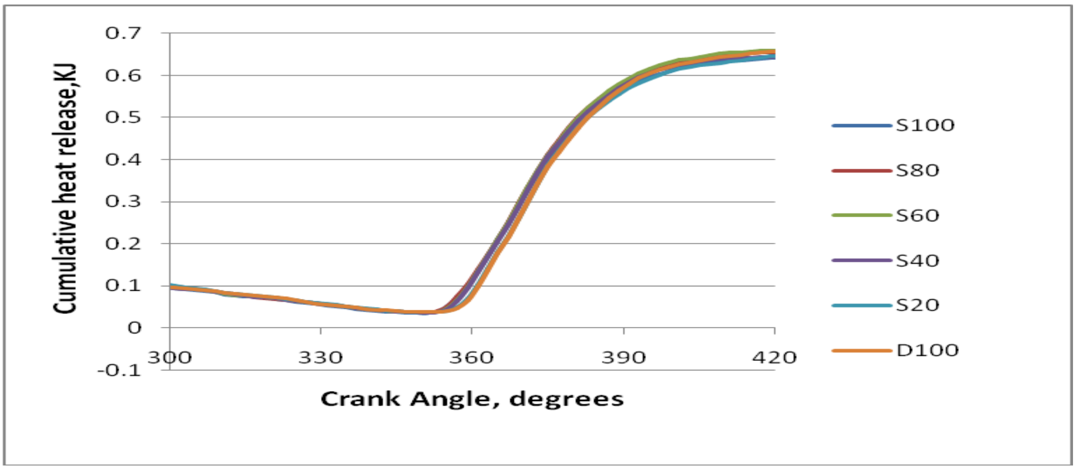

Fig 5.10 Variation of crank angle versus cumulative heat release rate

The fig-5.10 shows the variation of comulative heat transfer with crank angle. It is observed that from the fig-5.10 that all blends of simarouba biodiesl traces the same path as that of the diesel.initially the cumulative heat transfer decreases at first cycle and then increases in the second cycle as shown in the fig-5.3.3.

VI. Conclusion

- Specific fuel consumption increases as the concentration of simarouba biodiesel increases so we can observe that with 20% simarouba biodiesel blend almost matches with diesel fuel.
- Air fuel ratio for diesel is lower than simarouba biodiesel and its blends which is evident from the graph.
- The mechanical efficiency of diesel is slightly higher than the simarouba biodiesel blends and D100 and S20 are seen to be almost nearer to each other also from the graph.
- Brake thermal efficiency of simarouba biodiesel at 20% blend has slightly higher efficiency than diesel .
- The exhaust emission temperature of all the biodiesel are higher than the diesel and It is observed that, at full load the exhaust gas temperature is maximum, due to chemically correct ratio of air and fuel.
- The S20 has lower average percentage of change in 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.
- It is conclude that the combustion characteristics of all blends of simarouba oil is almost same as that of diesel.

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