Experimental investigation of IC engine performance using calophylum inophylum biodiesel

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Abstract. With a higher energy demand, the cost of oil is also increasing along with that the resources are vanishing at a very high pace and such conventional fuels creates environmental pollution, thus the best option is to find some clean, viable alternative for the same. Biodiesel is an available option and thus a better substitute for the IC engine fuel. It majorly restricts high emissions of the Carbon Monoxide(CO), Particulate Matter (PM), Hydrocarbon (HC) emission. Perversely, a number of experiments are conducted on a single blended bio fuel. This paper concentrates on two different bio-fuel blends with diesel. Calophylum Inophylum oil used for controlling the emission from the exhaust and subsequently improves the performance of an engine. The parameters are as follow: Brake thermal efficiency (BTE), specific fuel consumption and exhaust emission were noted. Lower the blends of biofuel more will be the thermal efficiency and thus it too reduces the specific fuel consumption. Calophylum Inophylum oil is used to prepare biodiesel blends ie (B20 and B40). The combustion characteristics investigated are cylinder gas pressure and heat release rate. Investigation is carried out at various loads and varying crank angles. The emissions at exhaust end were decreased while an increase was noted when the parts of biodiesel in the blend formed. This itself is sufficient to prove the viability and potential of the biofuel as an alternative to the conventional fuel being used to run an IC engine.

Keywords: Biodiesel, Alternative Fuel, Diesel engines, Exhaust gas, Combustion, Conventional fuel.

1. INTRODUCTION

Due to an aggressive approach towards the use of the petroleum based fuels for automobile and industrial application presently, the world-today is facing a severe problems like environmental pollution, energy deficiency, and global warming. Non-edible oils are gaining global attention prevent such crisis by developing alternative fuel sources. The work done by Jirahul et al. showed that the properties of Calophylum Inophylm biodiesel are consistent with most fuels. Fadhilullah et al. [1] investigated on many parameters for oil extraction from Calophylum Inophylm and concluded that an average tree can produce around 5.13 liters of oil per year. Channapattana [2] studied the performance characteristics of
the bio-oil known as hone oil. The results described the consumption of the fuel for biodiesel blends was more but the carbon monoxide and hydrocarbon emissions were reduced considerably.

Hwai Chyuan Ong [3] studied the characteristics of the Calophyllun Inophylum methyl ester prepared by acid and base catalyzed transesterification process and concluded that the properties of the same were in line with ASTM D6751 specifications. Muhammad Buhiya et al. [4] explained output results and trends of the calophyllum Inophylum biodiesel blends. The results revealed that the CO and HC emissions were reduced at the trade-off with increased NOx emissions. In the study by Shyamsundar Rajaraman et al. [5], it was studied a reduction in exhaust emissions but with a surge in NOx emissions. Fauzan et al. [6] studied the properties of the calophylum inophylum biodiesel for gas turbine application. The results showed that the biodiesel falls under ASTM D2880 fuel standard for gas turbine and can be pursued as an alternative fuel in gas turbines. Kumar et al. [7] took B20 of Jatropha oil ME and oil derived from fish and run it in a CI engine for including EGR and excluding EGR value. The outputs showed that the nitrogen oxide values declined significantly with the use of EGR technique. Gautam- Kumar [8] studied the output characteristics of the tallow biofuel, to find out that the engine performance parameters support the use of biodiesel and the difference between the power generated is unnoticeable, but however the BSFC is increased due to declining value of heating of the respective biodiesel. M. Agnese [9] investigated the process where combustion took place and along with that the process that considered the formation of the exhaust matter termed as the pollutants. A comparison is taken out as it is compared with the blends of mineral biodiesel [10].

From the presented literature it can be seen that the Calophyllum Inophylum biodiesel can readily be used as a potential fuel blend and with the use of EGR technique the obtained emission values can also be regulated. The goal of this study is to understand the output results of blend ratio of the fuel and Exhaust gas recirculation method on the descriptive diesel engine characteristics i.e. Performance Characteristics and Emission Characteristics.

2. MATERIALS AND METHODS

2.1 Preparation of fuel samples

The required fuel samples were made by blending the Calophyllum Inophylum biodiesel with mineral diesel in desired proportions. The Calophyllum Inophylum biodiesel was prepared sing a process termed as Trans-esterification. The B20 blend of the biodiesel was prepared by mixing 20 parts of CI biodiesel with 80 parts of mineral diesel with the help of stirring device known as magnetic stirrer. Similarly the B40 blend was prepared by mixing 40 parts CI biodiesel with 60 parts mineral diesel. The fuel blends were prepared according to volumetric ratios. The properties and characteristics of the respective blends were calculated as shown in Table 1.

| Density @ 15°C (kg/cm³) | Flash Point (°C) | Fire Point (°C) | Kinematic viscosity @ 40°C (mm²/s) | Calorific Value (MJ/kg) | Cetane index |
|-------------------------|-----------------|----------------|-----------------------------------|------------------------|-------------|
| B20 844.4                | 68.5            | 77             | 3.52                              | 41,688                 | 53.8        |
| B40 825.6                | 55              | 84             | 4.15                              | 38,459                 | 55.4        |
2.2 Experimental procedure
The experiment setup as shown in Table 2. The fuel injection parameters of the engine were taken as pressure of 220 bar and Crank angle (CA) of at 22° bTDC. The pressure of cylinder was calculated by a piezo-electric transducer fitted on the head of the cylinder. The emission characteristics like CO, HC and NOₓ emissions were calculated using an AVL Di-gas 444 analyser. The engine test runs were carried out by using B20 and B40 biodiesel blends for with and without 20% EGR at varying load. The similar tests were conducted for mineral diesel in order to obtain a reference value. In order to reduce the NOₓ emissions the most efficient method is EGR technique and for the same additional EGR setup was introduced. The EGR setup sends a certain proportion of output gas (exhausted) into the intake and combined with incoming supply. The EGR setup comprises of an EGR valve to control EGR rate and also an orificemeter in order to calculate the rate of flow of the gases being exhausted. The Exhaust Gas Recirculation value is calculated using the following equations.

\[
\% \text{ EGR} = \frac{\text{CO}_2 \text{ intake}}{\text{CO}_2 \text{ exhaust}} \times 100
\]  

(1)

Table 2: Specifications of diesel engine

| Type                                      | Single Cylinder, four stroke, common rail direct injection engine |
|-------------------------------------------|---------------------------------------------------------------|
| Bore x Stroke                             | 87.5 x 110 mm                                                 |
| Compression Ratio                         | 17.5 : 1                                                      |
| Rated Output                              | 4.5 kW                                                        |
| Rated Speed                               | 1500 rpm                                                      |
| Injection Pressure                        | 220 bar                                                       |
| Orifice Diameter                          | 13.5 mm                                                       |
| Co-efficient of Discharge                 | 0.65                                                          |

1a) Schematic Diagram of the setup

1b) Engine
Figure 1a-c. Experimental Setup

3. RESULTS AND DISCUSSION

3.1 Combustion characteristics

3.1.1 Heat release rate (HRR). Fig.2 describes the variation in HRR with various samples at 100 % power w.r.t angle of crank. It was studied that HRR got reduced and an increase in the net percentage of calophyllum inophyllum biodiesel was noted, which is the cause of the decreased calorific value. It further decreases when the EGR technique is used due to the lower combustion rate as compared to B20 and B40 blends without EGR.

Figure 2: Variation of Heat Realise Rate with Crank Angle
3.1.2 Cylinder pressure. Fig.3 depicts the change in the pressure in cylinder (i.e. In-cylinder Pressure) w.r.t the crank angle. It was studied that the pressure of the cylinder remains relatively constant, but was slightly decreases due to the use of 20% EGR as it tends to decrease the oxygen concentration in the fuel mixture and this results in lower combustion. The peak pressure for blends used i.e. B20, B20 + 20% EGR, B40, B40 + 20% EGR and mineral diesel are 67.5, 63.5, 68.1, 65.5 and 67.2 bar respectively.

3.2 Performance characteristics

3.2.1 Brake thermal efficiency (BTE). Fig.4. shows BTE of various fuel combinations in accordance to the brake power. The BTE increases with the increase in load for each fuel sample. The BTE decreases with blend ratio which may be a reason of the higher viscosity of the biodiesel consumed. A decrease in the BTE due to the activation of EGR method results in the reduction of the air to fuel mixture in recalculated gas comes out as an exhaust that results in oxygen deficiency and lower cylinder pressure during combustion. The BTE of B20 blend was decrease by 5.8% by the use of EGR at full load and for B40 it decreased by 5.5%, whereas the BTE of both the blends used were below the BTE value of that of the mineral diesel.

3.2.2 Brake specific fuel consumption (BSFC). The difference of BSFC value at various load can be seen in Fig.5. It was analysed that the BSFC value reduced with an increase in the load being applied. Further it was observed that the BSFC values increases with a net percentage increase in Calophyllum Inophyllum biodiesel due to its lower calorific value and may be due to changed ignition timing. With the application of EGR technique the BSFC further increases due to lower oxygen in intake air. It is clear in the depiction that at maximum Brake Power (B40 + 20% EGR) gives Maximum Brake Specific Fuel Consumption, while Mineral Diesel gives minimum BSFC.
3.3 Emission characteristics

3.3.1 CO emissions. The Carbon Mono-oxide emission at different load conditions can be observed in Fig.6. Under full load conditions, highest emission is produced by mineral diesel and lowest is by B40 blend. It can be seen that the CO emissions are lower for biodiesel blends that are B20 and B40, as they have lower carbon content when compared with the mineral diesel. The EGR technique is used in order to increase the CO emissions due to incomplete combustion occur in the respective process. The CO output values were increased by 4.5% and 10.5% for B20 and B40 blends respectively when tested with 20% EGR at full load condition.

Figure 4: Brake Thermal Efficiency Vs Brake Power

Figure 5: Brake Specific Fuel Consumption Vs Brake Power
3.3.2 HC emissions. Fig. 7 describes the Hydro-Carbon emissions for all samples held with changing load conditions. Bar chart clearly shows that an increased emission was noted when run at increased load and lower HC emissions due to blending of Calophylum Inophylum biodiesel due to its oxygenated nature. But the use of EGR tends to increase the HC emissions by an average value of 11.9%, and this is possibly due to incombustion (ie lack of oxygen). The HC emissions were significantly reduced by 13% and 24.6% for the blends being prepared that were (B20 and B40) respectively. The comparison is done in respect to the mineral diesel when tested at maximum load conditions.

3.3.3 NO\textsubscript{X} emissions. The Nitrogen Oxide emissions at various loads are depicted in Fig.8. NO\textsubscript{X} emission outputs increased and thus therefore the load and blending ratio of the blended biodiesel increased too. The NO\textsubscript{X} emission increased by 4.8% and 7.3% for B20 blend and B40 blend respectively at maximum load conditions. While B40 blend tends to top the emission value throughout the process that was investigated. The use of EGR technique reduces the NO\textsubscript{X} emissions significantly from 5% to 7% in blended biodiesel when tested at maximum load condition.

![CO Emissions with Load](image_url)

**Figure 6:** Variation of CO emissions with Load
4. CONCLUSIONS

The major characteristics of the diesel engine used, that consumes biodiesel blends of the Calophylum Inophylum biodiesel that incorporates the EGR technique too, were investigated and the following conclusions can be drawn from the results obtained from the experimental investigation.

4.1 The brake thermal efficiency of B20, B20 with 20% EGR, B40 and B40 with 20% EGR were reduced by 2.9, 8.5, 4.8, 10% respectively, the comparison was done with respect to the mineral diesel when operated at maximum load conditions.
4.2 The maximum pressure resulted for every test done with both type of fuel occurred approximately at the same period of time.

4.3 The CO emissions were reduced by 9.5% and 26 % for both biodiesel blends ie (B20 and B40) as compared to mineral diesel but increased by 7% , which is due to the use of EGR method at full load.

4.4 The HC emissions the lowest for B40 blend at 52 ppm followed by B20 at 60 ppm and were increased by 11.5% and 15.3% respectively due to the employment of EGR technique. The HC emissions were lower for all in respect of mineral diesel.

4.5 The NOX emissions as recorded while testing were increased by 90 ppm and 135 ppm for B20 and B40 blends when put parallel to mineral fuel at 100% condition, which were reduced by 103 ppm and 117 ppm respectively by the use of EGR method at full load condition.

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