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# Effect of Performance, Combustion and Emission Characteristics on A CI Engine Fueled with Calophyllum Inophyllum (Polanga) Biodiesel

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***Abstract*:- Due to the increase in population and economic growth of the nation, particularly in growing countries like India, has resulted in huge demand of energy sources. Due to reduction of non-renewable petroleum sources and recent hike in petroleum prices and lack of availability of petroleum products have generated interest in extraction of energy from renewable energy sources wherein the biodiesel plays an important role which is derived from plant origin for diesel engines. This research work refers to the biodiesel production by the process of transesterification of Calophyllum inophyllum oil with methanol as a solvent, calcium oxide (CaO) as a catalyst. The obtained Calophyllum inophyllum biodiesel (methyl ester) from transesterification process is blended with the neat diesel in required proportion such as B10, B20, B30, B40 and B100 and their properties such as flashpoint, fire point, kinematic viscosity, etc., are examined and used to run 4-stroke, CI engine without making any modification to engine and study the performance, combustion and emission characteristics of engine fueled with the Calophyllum inophyllum methyl ester and it's blends. The results are compared with the same engine when fueled with conventional petroleum diesel and tabulated.**

***Key words: Polanga oil methyl ester (POME), Neat diesel, Transesterification, Diesel Engine, Exhaust Emissions.***

## 1. INTRODUCTION

In the present days, the world has been confronted with environmental and energetic crises due to depletion of resources and increased population as well as environmental pollution. Hence, it is important to search for an alternative low cost fuel for every day usage, which should be sustainable and also ecofriendly. Biodiesel is considered as an assuring alternative fuel because of improved lubricity, higher flash point, bettered biodegradability, reduction of most exhaust emissions and decreased toxicity over conventional diesel [1]. The production cost of biodiesel is high compare with the cost of diesel obtained from petroleum; this was the main drawback of biodiesel production. However, by improving the production process, the cost of biodiesel could certainly be lowered [2]. Bio diesel or Fatty acid methyl esters (FAME) is an inexhaustible energy resource that can be synthesized from vegetable oil and animal fat through chemical reaction called transesterification. For conventional diesel the biodiesel is considered as the better substitute, it is made from various oilseeds in an industrial practice [3]. Transesterification, pyrolysis, emulsification and dilution processes preferred for biodiesel production but among all these transesterification process is most suitable process because product of this reaction that is glycerol has more commercial values [4]. Transesterification is the chemical reaction occurs between triglycerides and alcohol to produce biodiesel in the presence or absence of catalyst. Butanol, methanol, propanol and ethanol are the commonly used short chain alcohols. However, methanol is the most preferred alcohol for biodiesel production [5, 6]. Transesterification usually performed in presence of catalyst. Catalysts are of two types Heterogeneous catalyst and Homogenous catalyst, where Heterogeneous catalysts are more acceptable because of their main advantages such as separation of catalyst is easy and pure final products can be obtained [7, 8]. With all heterogeneous base catalysts, most of the researches prefer catalysts such as CaO, MgO, SrO, BaO etc. Heterogeneous base catalyst named as calcinated CaO is used for the present work. The homogeneous base catalyzed transesterification leads to the increase in production cost and environmental impact due to production of great amount of water waste in removing the dissolved catalyst from the reaction mixture [9, 10]. In this work Calophyllum inophyllum methyl ester is chosen as suitable source to study the performance, combustion and emission characteristics of engine fueled with the Calophyllum inophyllum methyl ester and its blends. The results are compared with conventional petroleum diesel.

## 2 MATERIAL AND METHODS

### *2.1 Material*

The Calophyllum inophyllum was collected from Bennarugatta forest Bengaluru, Karnataka. Collected waste Calophyllum inophyllum oil was heated at 100 ºC to remove water and unwanted materials present in the oil. After, the scum oil was filtered to remove suspended particles and purified oil was used for transesterification. Methanol and Calcium oxide was purchased from Fisher scientific, Bengaluru. Prior to transesterification calcium oxide catalyst was calcinated to 900 ºC to increase the activity of the catalyst.

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*2.2 Transesterification*

1 litre of Calophyllum inophyllum oil was taken in a round bottom flask fitted with a condenser, thermometer and magnetic stirrer as shown in Fig.2.1. Initially, the oil was heated up to 60 ºC, then prepared solution (2.80% of calcium oxide and 11:1 methanol to oil molar ratio) was added to the oil, then reaction was carried out for about 3 hours with a agitation speed of 750 rpm. After completion of reaction, the mixture is subjected to settling tank for 10 hours which results in the formation of three phases namely catalysts (bottom), glycerin (middle) and biodiesel (top) were separated. The catalyst and glycerin was drained out and separated biodiesel was decalcified using citric acid to get pure biodiesel. The transesterification of Calophyllum inophyllum oil to biodiesel is as shown in the Fig.2.1

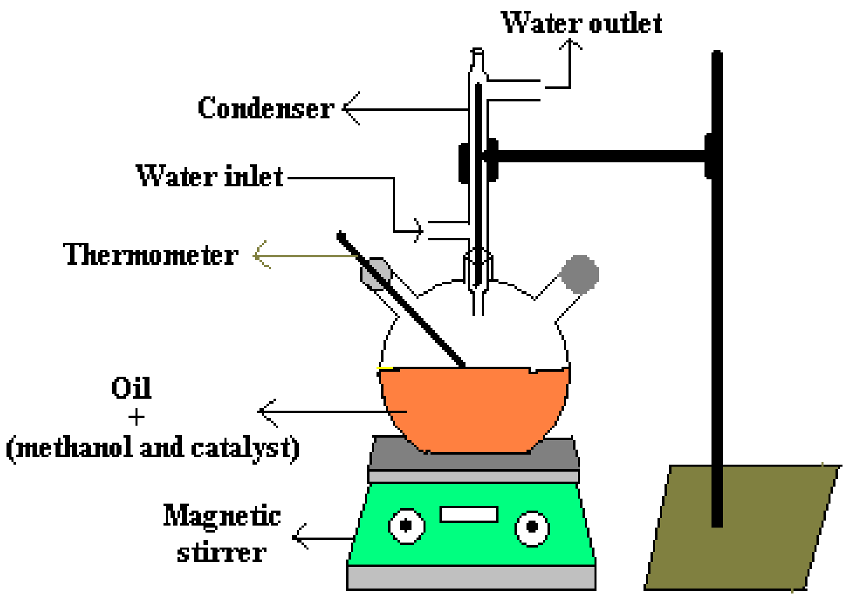


Fig. 2.1. Schematic diagram of transesterification set up

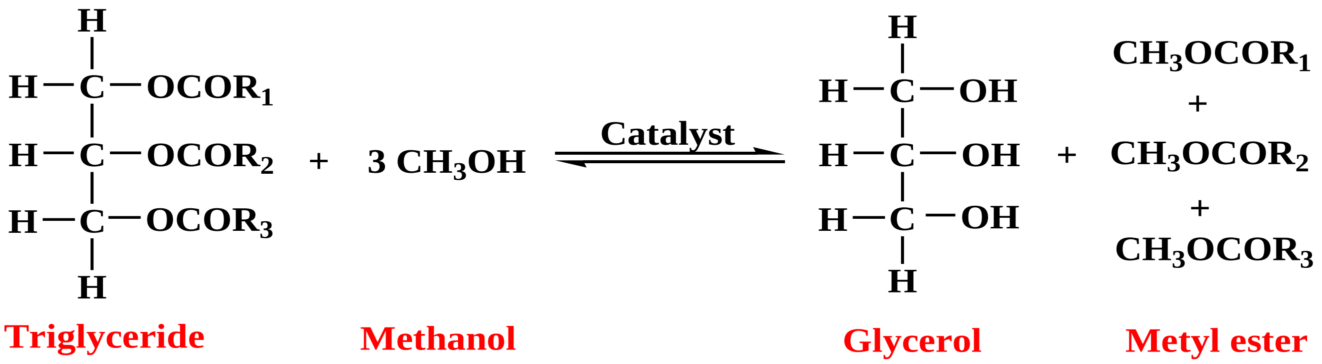


Fig. 2.2 Shows transesterification reaction and mechanism of reaction

*2.3 Biodiesel fuel properties*

The following fuel properties of produced Calophyllum inophyllum biodiesel were determined: density (ASTM D4052), flash point (ASTM D93), kinematic viscosity (ASTM D445), calorific value (ASTM D240), carbon residue (ASTM D4530), cloud point (ASTM D2500), pour point (ASTM D97). Test samples which include diesel and biodiesel test blends (B10, B20, B30, B40 were prepared by v/v % basis and B100) were used in diesel engine to evaluate the engine properties.

*2.4 Engine test procedure*

Test samples were conducted under steady state conditions i.e. without any changes in the engine to evaluate performance, combustion and emissions. The timing for various aspects like injection timing and injection pressure was kept same as recommended by the manufacturer (Kirloskar TAF-1). The tests were conducted without changing any physical conditions. Test samples were tested at five different load conditions that are 0%, 25%, 50%, 75% and 100% load. Four reading were taken for every blend and the average of all was mentioned in the result. The specification of engine test rig is tabulated in Table 1.

| | |
|---|---|
| Make and model | Kirloskar TAF-1 |
| No. of cylinders | Single cylinder |
| Rated power | 5.2 kW |
| Bore | 87.5 mm |
| Stroke | 110 mm |
| Rated speed | 1500 rpm |
| Injector opening pressure | 200 bar (20 MPa) |
| No. of injector holes (diameter) | 3 (0.3 mm) |
| Capacity | 0.661 L |
| Cooling | Air-cooled |

Table 1. Engine specifications.

## 3. RESULTS

### *3.1 Brake Thermal Efficiency (BTE)*

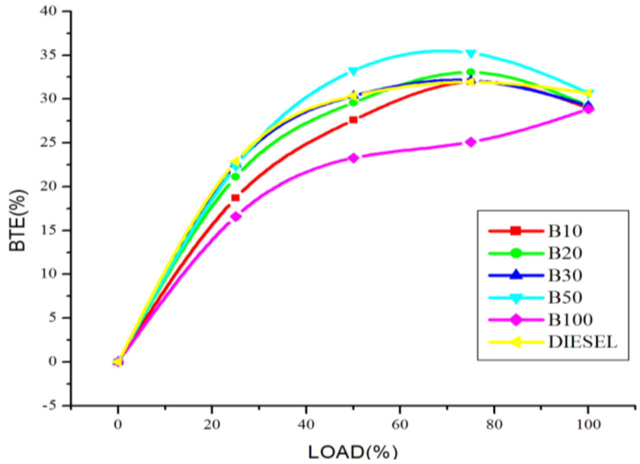


Fig 3.1: Brake thermal efficiency for IP of 200bar& 17.5:1 CR versus load

The fig 3.1 represents the variation of brake thermal efficiencies of diesel, Calophyllum inophyllum oil biodiesel and its blends with petroleum diesel in proportions of B100, B50, B30, B20 and B10. B100 being pure Calophyllum inophyllum oil methyl ester. It is seen from the figure 3.1 that for all the fuels brake thermal efficiency increases significantly with increase in load, this is because there are less losses at higher loads. It is clear from the Figure that brake thermal efficiency of the POME (B100) is lesser than that of diesel and the plot of B30 (i.e. 70% diesel and 30% biodiesel ) almost follows the plot of diesel and the plot B50 has higher brake thermal efficiency at all loads.

### *3.2 Brake Specific Fuel Consumption (BSFC)*

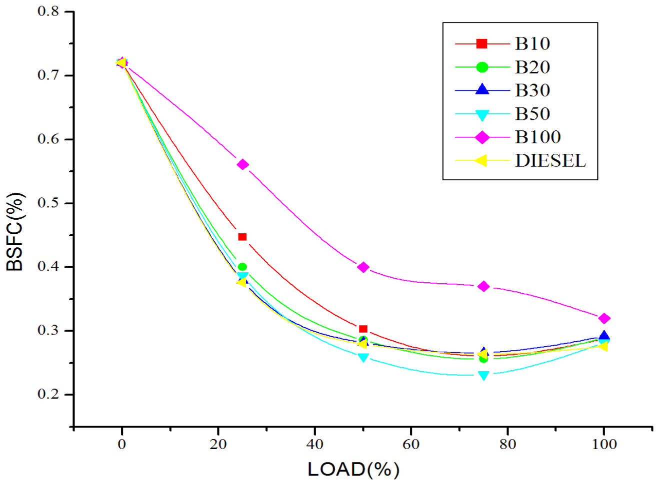


FIGURE 3.2: BSFC for IP of 200bar &17.5:1 CR versus load

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The figure 3.2 give the clear picture of variation of BSFC v/s load for Calophyllum inophyllum methyl ester . It is noticed that the trend of plot decreases as the load increases, this is because of the fact that at higher load there are less losses and hence lesser amount of fuel is consumed. From the figure 3.2 it is seen that BSFC plot for the blends B30 and B20 are closer to the plot of petroleum-diesel compared to other blends, but the pure Calophyllum inophyllum methyl ester has higher BSFC compared to other blends because POME has lesser calorific value compared to diesel and its blends with diesel hence to compensate the deficiency in calorific value more fuel will be drawn in to the engine hence increasing BSFC for B100.

*3.3 EXHAUST GAS TEMPERATURE (EGT)*

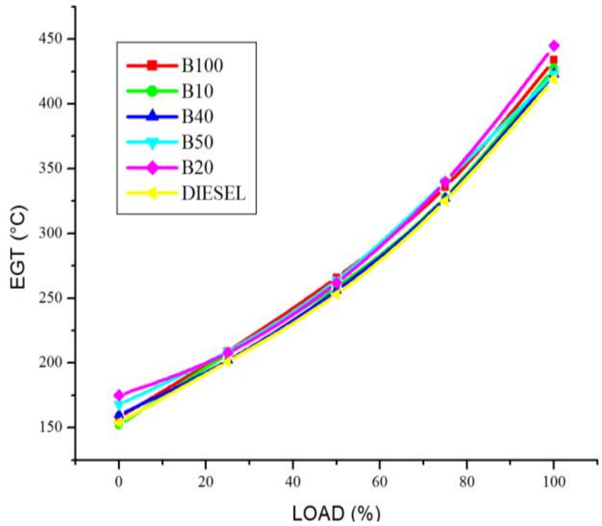


FIGURE 3.3: EGT for IP of 200bar &17.5:1 CR versus load

From the figure 3.3 it is evident that there is not much change in the plot of exhaust gas temperature of clean biodiesel , diesel , and biodiesel-diesel with variations in load , and it also shows that as the load on the engine increases the trend of exhaust gas temperature increases for all the blends this is because as the load on the engine increases more fuel is burnt and hence more heat is liberated in the engine. The exhaust gas temperature of clean diesel is comparatively lower than the biodiesel and its blends. This is because biodiesel has comparatively less calorific value hence to compensate this deficiency in calorific value more fuel will be burnt hence the exhaust gas temperature of biodiesel and its blends increases.

*3.4 CARBON MONOXIDE EMISSION*

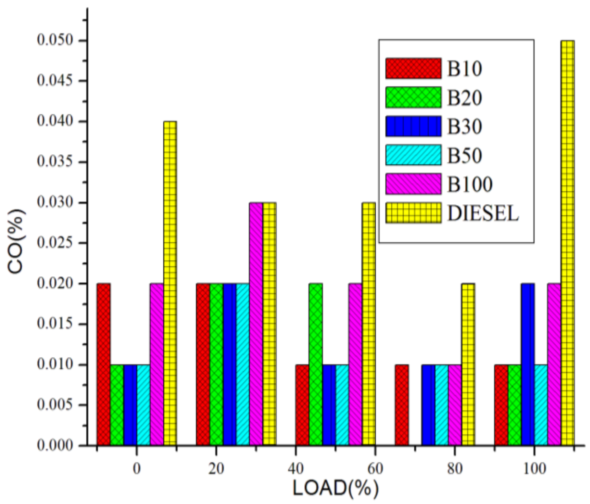


FIGURE 3.4: CO emission versus load for IP of 200bar and 17.5:1CR

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From the figure 3.4 it is clear that the CO for all the loads and for all blends have lower CO emission compared to the conventional petroleum diesel , this is because of the fact that the oxygen content in the biodiesel is more compared to petroleum diesel , hence with increasing the blending ratio of biodiesel in the diesel CO emission decreases, but for the blend B100 it is evident that the CO emission is more compared to all other blends, it is because since B100 has higher viscosity it results in poor atomization and hence results in improper combustion.

*3.5 HYDRO CARBON EMISSION*

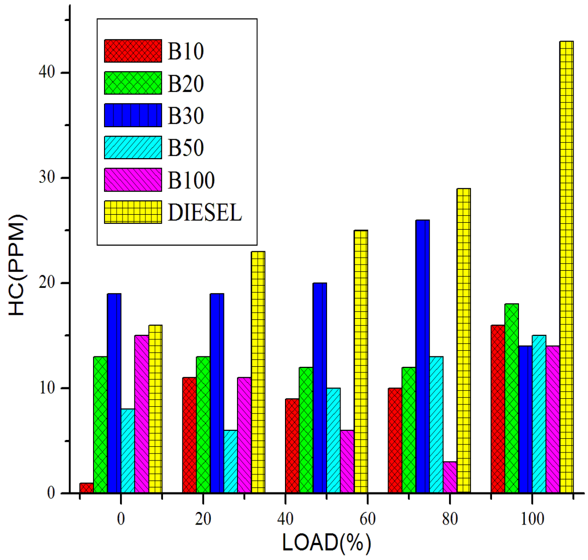


FIGURE 3.5: HC emission versus load for IP of 200bar and 17.5:1CR

The figure 3.5 shows the variation of hydro carbon emission versus load. From the figure it is clear that the hydrocarbon emission for B100 is lower than the other blends at all most all loading condition this is because of the presence of excess oxygen content in the clean biodiesel which aids in the combustion of fuel. The hydrocarbon emission plot for B30 is closely comparable with diesel plot at all loads. At 0% loading the hydrocarbon emission of B30 is found to be higher than the diesel and B10 has almost negligible amount of hydrocarbon emissions.

*3.6 NITROUS OXIDE EMISSION*

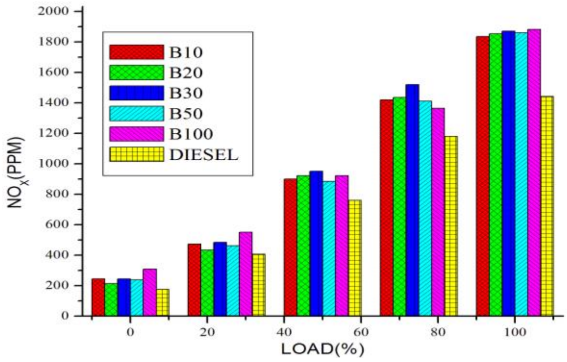


FIGURE 3.6: $NO_x$ emission versus load for IP of 200bar and 17.5:1CR

The figure 3.6 indicates the variation of nitrogen oxide emission with varying load, it is seen that the plot follows the trend of increasing nitrogen oxide emission with increase in load for all blends of fuel and diesel . This is because as the load on the engine increases the combustion chamber temperature increases due to the combustion of more fuel, due to the existence of added oxygen content and high temperature during the combustion of B100, $NO_x$ emission is maximum for it.

*3.7 CARBON DIOXIDE EMISSION*

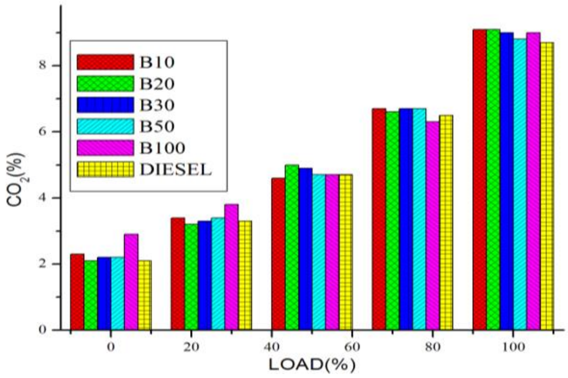


FIGURE 7.13: $CO_2$ emission versus load for IP of 200bar and 17.5:1CR

Figure 7.13 shows the variation of carbon dioxide emission for the various blends of Calophyllum inophyllum methyl ester versus the load on engine . The trend of the plot shows increase in carbon dioxide emission as the load increases , this shows that the combustion efficiency of biodiesel and its blends higher compared to pure petroleum diesel. And also as the load increases the more fuel is injected in to the engine and increases the combustion rate hence the carbon dioxide emission is more for all the fuels at 100% load compared to partial load and also we can easily make out from the figure that $CO_2$ emission for biodiesel and it's blends are almost greater than diesel at all loads , this ensures clean combustion of fuel inside the engine cylinder.

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