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"Experimental Investigation of Compressed Ignition Engine Using Karanja Oil Methyl Ester (KOME) as Alternative Fuel"

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ABSTRACT

Biodiesel is a fatty acid alkyl ester which is renewable, biodegradable and non toxic fuel which can be derived from any vegetable oil by transesterification process. One of the popularly used non edible biodiesel in India is karanja oil methyl ester (KOME). In the present investigation, karanja oil based methyl ester (biodiesel) is produced by using calcinated calcium oxide, a heterogeneous base catalyst by transesterification process. The properties of KOME thus obtained are comparable with ASTM biodiesel standards. The produced KOME is blended with diesel were tested for their use as a substitute fuel for diesel engine. Experiments were conducted for Injection pressures of 200bar and 225bar, keeping compression ratio of 24:1 as constant, to study the performance and emission characteristics of a direct injection diesel engine using blends of karanja methyl esters with diesel on a 10, 20, 30, 40 and 50% volume basis, respectively. Thus acquired data were analyzed for various parameters such as brake thermal efficiency, brake specific fuel consumption, exhaust gas temperature, Carbon monoxide (CO), hydrocarbon (HC), carbon dioxide (CO_2) and nitrogen oxide (NOx) emissions against varying Load.

Keywords – Biodiesel, calcium oxide, Injection pressure, karanja oil methyl ester, Transesterification.

1. INTRODUCTION

Diesel engine is a popular prime mover for transportation, agricultural machinery and industries. Diesel fuel is largely consumed by the transportation and agricultural sectors. Import of petroleum products is a major drain on our foreign exchange sources and with growing demand in future years the situation is likely become even worse. Diesel and petrol engines are the main sources of carbon dioxide, carbon monoxide and un-burnt hydrocarbon emissions and increase in carbon dioxide, carbon monoxide levels in the atmosphere leads to global warming and green house effect. The world is on the brink of energy crises. Efficient use of natural resources is one of the fundamental requirements for any country to become self sustainable with the fossil fuel depleting very fast, researchers have concentrated on developing new agro based alternative fuels, which will provide sustainable solution to the energy crises. There are more than 300 different species of trees in India, which produces oil. Most of these trees are wild and therefore once established will look after themselves.[1] Since India is net importer of vegetable oils, edible oils cannot be used for production of bio diesel. India has the potential to be a leading world producer of bio diesel, as bio diesel can be harvested and sourced from non edible oils like Jatropha curcus, Pongamia pinnata, Neem, Mahua, caster, linseed, Kusum, etc. Some of these oils produced even now are not being properly utilized. Out of these plants, India is focusing on Pongamia pinnata, which can grow in arid and wastelands. Oil content in the Pongamia seed is around 30-40%. India has about 80-100 million hectares of wasteland, which can be used for Pongamia and other non edible plants.[2] Implementation of bio diesel in India will lead to many advantages like green cover to wasteland, support to agriculture and rural economy and reduction in dependence on imported crude oil and reduction in air pollution.[3]

Currently Fatty acid methyl esters (FAME) is commonly produced by performing a transesterification reaction with homogeneous base catalysts such as KOH or NaOH dissolved in methanol under mild conditions but the produced FAME is required to be purified. Moreover, the total cost of this process is not sufficiently competitive as compared to the cost of petroleum–derived diesel fuels [4]. In order to solve these problems, several types of FAME production processes have been studied: homogeneous acid catalyzed process, supercritical process, enzymatic process [5] and heterogeneous catalyst process [4,6]. The transesterification catalyzed by solid base is a bright technology for the noble process featuring the fast–reaction rate under mild reaction conditions. In this paper our interests were focused on CaO for the purpose of studying the noble process using the solid base catalyst from the view point of their economical advantages, because it is referred to CaO was quite active in transesterification of soybean oil with refluxing methanol [6].

In this Paper Karanja oil based methyl ester (biodiesel) is produced by using calcinated calcium oxide, heterogeneous base catalyst by transesterification process. The properties of KOME thus obtained are compared with ASTM biodiesel standards [9]. The produced KOME is blended with diesel were tested for their use as a substitute fuel for diesel engine. Experiments were conducted to study the performance and emission characteristics of a direct injection diesel engine using blends of karanja methyl esters with diesel on a 10, 20, 30, 40 and 50% volume basis, respectively. Thus acquired data were analyzed for various parameters such as brake thermal efficiency, brake specific fuel consumption, exhaust gas temperature, Carbon monoxide (CO), hydrocarbon (HC), carbon dioxide (CO_2) and nitrogen oxide (NOx) emissions against varying Load.

Table.1: comparison of Homogeneous & Heterogeneous Method

HOMOGENEOUS METHOD	**HETEROGENEOUS METHOD**
Reaction is very fast	Relatively slow process
Reaction is 100% complete	Conversion is relatively poor
Catalyst dissolved in the reaction mixture	Catalyst does not dissolved in the reaction mixture
Purification is difficult	Purification is much easier
Purification by water wash	Biodiesel purification by de calcification
Glycerin is crude need further purification	Glycerin is crude need further purification
Catalyst cannot be recycled	Catalyst can be recycled
Process is cheaper	Process is presently expensive

2. EXPERIMENTAL PROCEDURE

2.1. Preparation of Solid base catalyst

Calcium oxide (24 gm) was dipped in 200 ml of ammonium carbonate solutions (12% by wt) then the mixture was stirred for 30 minutes at room temperature. After filtration and drying the precipitate at 110ºC till constant weight, the dried solid was milled and sieved (48 mesh) then calcined at 900 ºC for 1.5 hours. After cooling in desiccators to room temperature the base CaO catalyst is ready to use.

2.2. Production of KOME by Transesterification

Transesterification also called alcoholysis is the displacement of alcohol from an ester by another alcohol in a process similar to hydrolysis, except that an alcohol is employed instead of water. Suitable alcohols include: methanol, ethanol, propanol, butanol, and amyl alcohol. Methanol and ethanol are utilized most frequently. This process is widely used to reduce the viscosity of triglycerides, thereby enhancing the physical properties of fuel and improve engine performance. Thus fatty acid methyl ester (also known as biodiesel) is obtained by transesterification. Fig 2 shows the flow chart for Karanja oil transesterification catalyzed by calcium oxide. Measured quantity of esterified karanja oil is taken in a 3 neck flask with reflux condenser, the oil is heated up to 70°C.When it reaches 70°C required quantity of methanol and calcinated calcium oxide catalyst are added. The reaction time is about 3hrs. Transesterified oil is transferred into separating funnel and allowed to settle for about 7-8 hrs then three layers was formed as shown in fig 1, upper layer was biodiesel, middle layer was of glycerin and the last layer was catalyst. The catalyst and glycerin are separated. The advantage of heterogeneous method is that the recovered catalyst can be reused. The Yield after this process was found to be 88-90% of biodiesel (850-900ml).

Transesterification process parameters

- Methanol to oil molar ratio :9:1
- Amount of calcinated CaO catalyst :2%(w/v)
- Reaction Temperature :70°C
- Reaction Time :3 hours

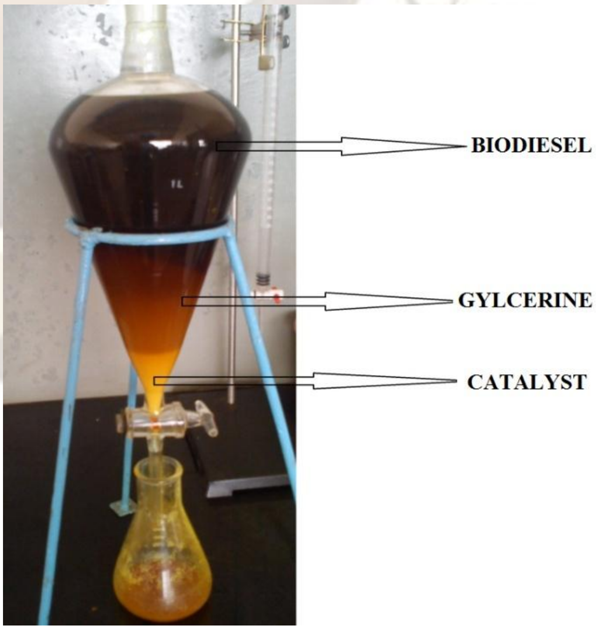

Figure 1: Transesterified Bio-diesel with three layer

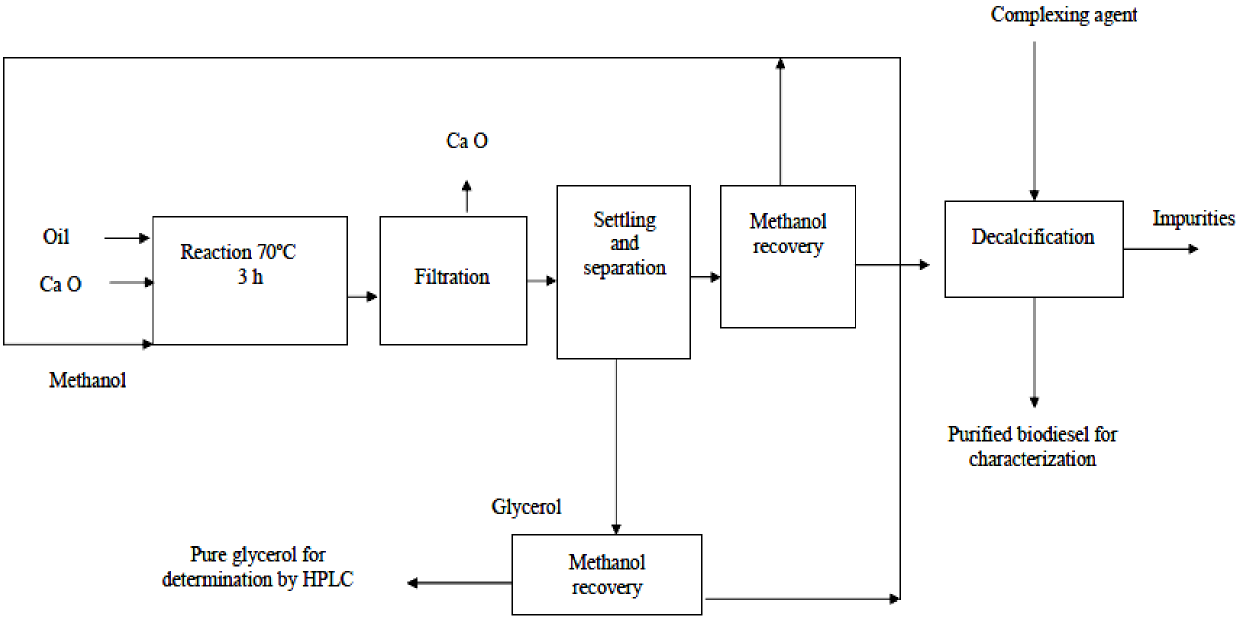

Figure 2: Flow chart for Karanja oil transesterification catalyzed by calcium oxide

2.3. Properties of Diesel & KOME

Biodiesel blends of karanja methyl esters with diesel on a 10, 20, 30, 40 and 50% volume basis was prepared and fuel properties are measured following standard procedure. The properties of KOME (B100) and Prepared blends are compared with ASTM biodiesel standards as shown in TABLE.2

Table 2: Properties of Diesel & KOME

Sl.No	PROPERTIES	STANDARD	RANGE*	B10	B20	B30	B40	B50	B100	DIESEL
1	Flash point (°C)	ASTM D93	>110	75	79	82	86	89	173	54
2	Viscosity (Cst) at 40°C	ASTM D445	1.9-6.0	3.05	3.19	3.4	3.85	4.16	5.9	2.54
3	Specific gravity	ASTM D4052	0.87-0.90	0.83	0.8375	0.842	0.8475	0.85	0.885	0.815
4	Calorific value (kJ/kg)	ASTM D240	--	37492	37378	37262	37091	36918	36000	42141

* For B100

2.4. Engine Test

The experimental work carried out for the objective, requires an engine test set-up adequately instrumented for acquiring necessary performance and emission characteristics. Karanja methyl ester blends (Biodiesel-B10, B20, B30, B40 and B50) and pure Diesel were used to test a single cylinder, 4-stroke, water-cooled diesel engine having a rated output of 5.2 kW at 1500 rpm and a compression ratio of 24:1. Injection pressure of 200bar and 225bar are chosen for comparing the experimental data. The engine was coupled with an eddy current dynamometer to apply different engine loads. The emissions from the engine were studied at different engine loads. After the engine reached the stabilized working condition, emissions like CO, HC, NOx and exhaust temperature were measured using a smoke-meter and an exhaust gas analyzer. The experimental set-up is as shown in figure 3

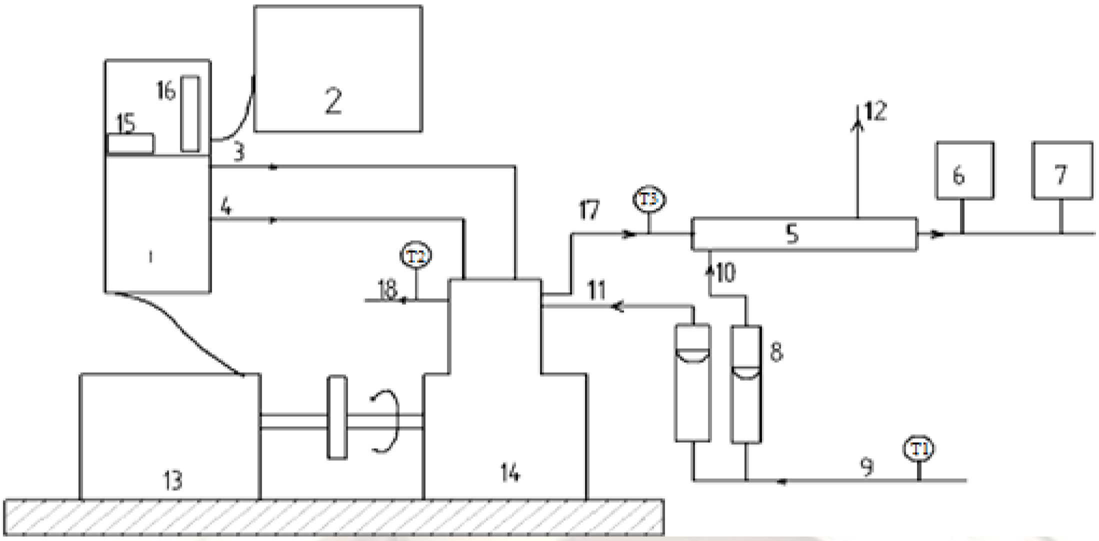

Figure 3: Schematic Diagram of the Experimental Set-up

1 = Control Panel
2 = Computer system
3 = Diesel flow line
4 = Air flow line
5 = Calorimeter
6 = Exhaust gas analyzer
7 = Smoke meter
8 = Rota meter
9, 11= Inlet water temperature
10 = Calorimeter inlet water temperature
12 = Calorimeter outlet water temperature

13=Dynamometer
14 = CI Engine
15 = Speed measurement
16 = Burette for fuel measurement
17 = Exhaust gas outlet
18 = Outlet water temperature
T1= Inlet water temperature
T2 = Outlet water temperature
T3 = Exhaust gas temperature

3. RESULTS AND ANALYSIS

This paper compares brake specific fuel consumption, brake thermal efficiency, Exhaust gas temperature and exhaust emissions of KOME and its blends with those of diesel.

3.1. Performance characteristics

Engine performance characteristics are the major criterion that governs the suitability of a fuel. This study is concerned with the evaluation of brake Thermal efficiency (BTE) and brake specific fuel consumption (BSFC) of the KOME diesel blends.

3.1.1. Brake Thermal Efficiency(BTE)

Brake thermal efficiency is defined as the ratio of energy in the brake power, to the input fuel energy in appropriate units. [7, 8]

The variation of Brake Thermal efficiency for injection pressure (IP) of 200bar and 225bar with load for different fuel blends are shown in fig 4 & fig 5

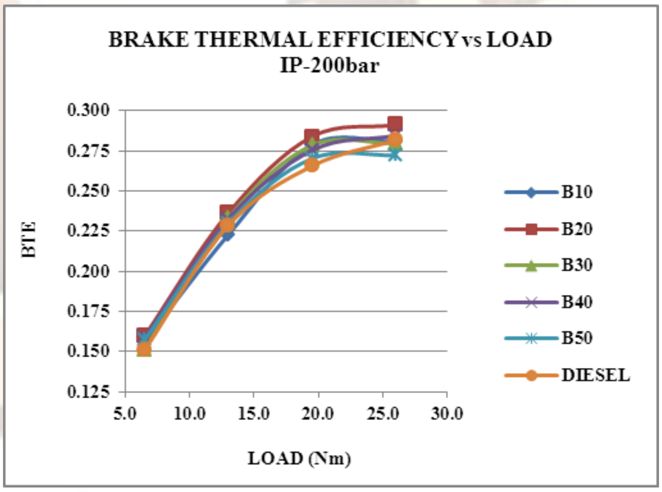

Figure 4: Brake thermal efficiency for IP of 200bar vs. Load

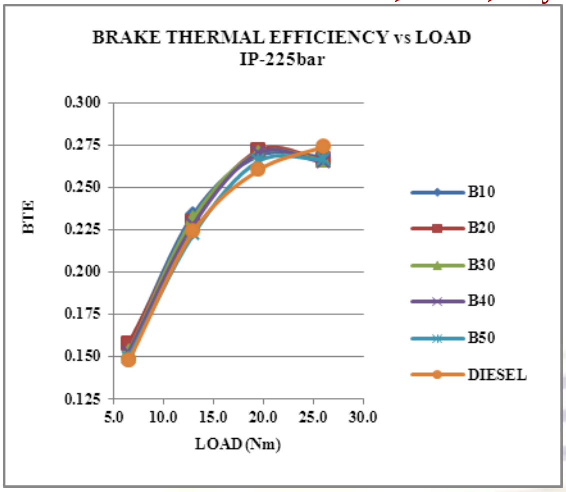

Figure 5: Brake thermal efficiency for IP of 225bar vs. Load

In all the cases brake thermal efficiency is increased due reduced heat loss with increase in load. The maximum efficiency obtained in this experiment was 29.10% (B20), 28.5% (B40) for 200bar IP and 27.2% (B20), 27.0% (B30, B40) for 225bar IP. But considering the viscosity, B20 is the better option and this value is comparable with the maximum brake thermal efficiency for diesel (28.2% and 27.4% for 200bar & 225bar). From the above graphs, it is found that brake thermal efficiency for biodiesel in comparison to diesel engine is a better option for part load on which most engine runs.

3.1.2. Brake Specific Fuel Consumption (BSFC)

Specific fuel consumption is defined as the amount of fuel consumed for each unit of brake power developed per hour, [7, 8].

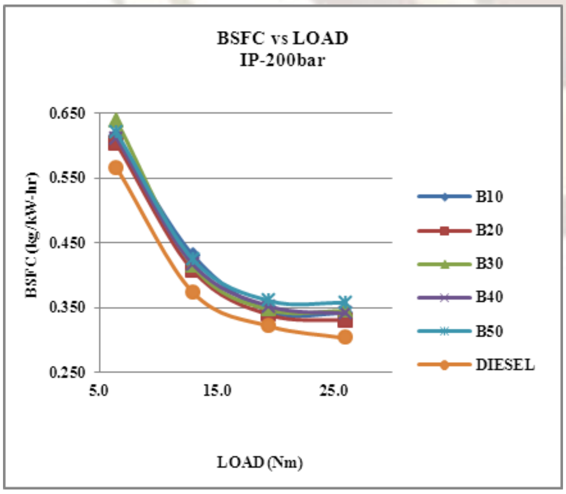

Figure 6: BSFC for IP of 200bar vs. Load

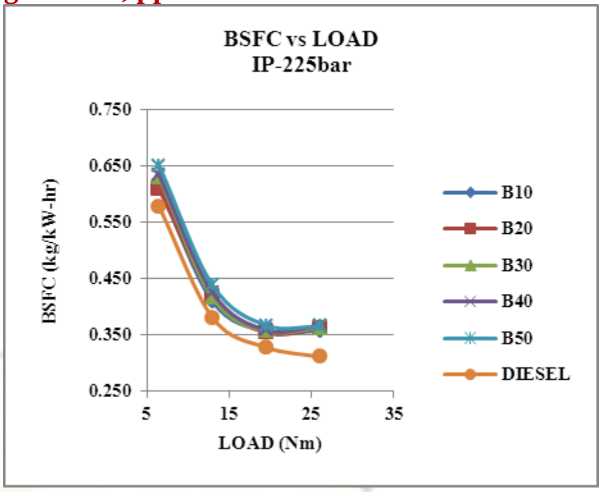

Figure 7: BSFC for IP of 225bar vs. Load

Fig 6 & Fig 7 shows the variation of brake specific fuel consumption of diesel and various blends of karanja methyl ester at different loads for IP of 200bar & 225bar respectively. It is found that the specific fuel consumption for the blend B20 is close to diesel. However if the concentration of karanja oil in the blend is more than 30% the specific fuel consumption was found to be higher than diesel at all loads. This is because of the combined effects of lower heating value and the higher fuel flow rate due to high density of the blends. Higher proportions of karanja oil in the blends increases the viscosity which in turn increased the specific fuel consumption due to poor atomization of the fuel.

3.1.3. Exhaust Gas Temperature (EGT)

Fig 8 & Fig 9 shows the variation of exhaust gas temperature with load for various blends and diesel.

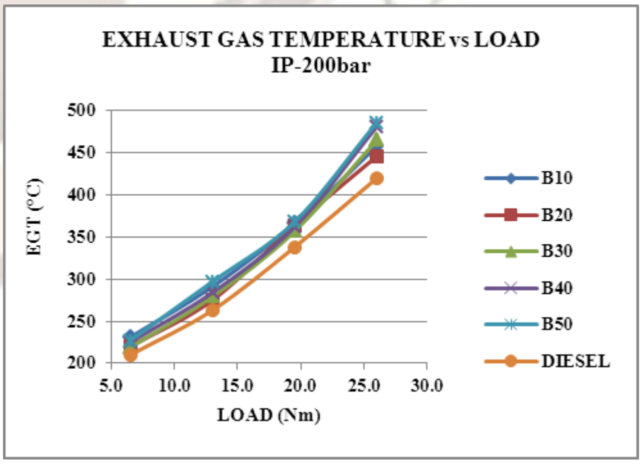

Figure 8: EGT for IP of 200bar vs. Load

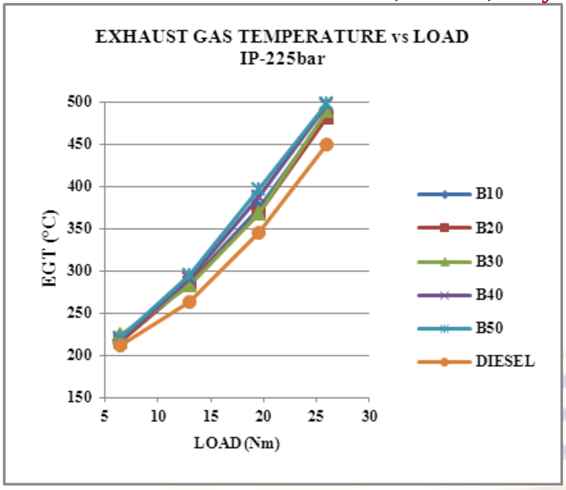

Figure 9: EGT for IP of 225bar vs. Load

The results show that the exhaust gas temperature increases with increase in load for all blends. At all loads, diesel was found to have the lowest temperature and the temperatures for various blends show an upward trend with increasing concentration of karanja oil in the blends. The biodiesel contains oxygen which enables the combustion process and hence the exhaust gas temperatures are higher.

3.2. Emission Characteristics

With problem like global warming ozone layer deletion and photochemical smog in addition to widespread air pollution automotive emission are placed under the microscope and every possible method is attempted to reduce emission. Hence this study compares the emission of pollutants nitrogen oxides, carbon monoxide, unburned hydrocarbon emissions and Carbon dioxide of karanja methyl ester and its blend with diesel.

3.2.1. Carbon Monoxide Emission (CO)

Carbon Monoxide is measured by an exhaust analyzer in percent (%) or parts per hundred. CO is a byproduct of combustion; therefore, if combustion does not take place, carbon monoxide will not be created. The emissions of carbon monoxide are toxic. Based on this premise, when a misfire occurs, the carbon monoxide that would have normally been produced during the production process is not produced. Generally speaking, on fuel injected vehicles, high CO means too much fuel is being delivered to the engine for the amount of air entering the intake manifold.

The comparative analysis is as shown in Fig 10 & Fig 11. Biodiesel blends give less carbon monoxide as compared to diesel due to complete combustion. When the percentage of blend of biodiesel increases, carbon monoxide decreases. This is due to more amount of oxygen content of biodiesels that result in complete combustion of the fuel and supplies the necessary oxygen to convert CO to CO_2. At 26 Nm load, all blends & neat diesel shows sudden increase in CO emissions.

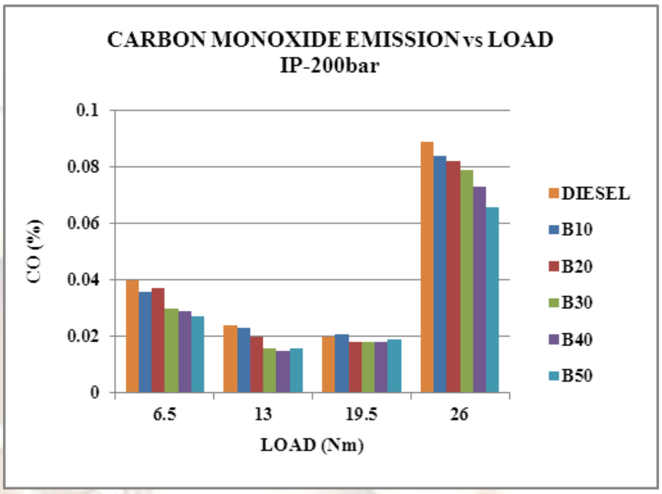

Figure 10: CO emission vs. Load for IP of 200bar

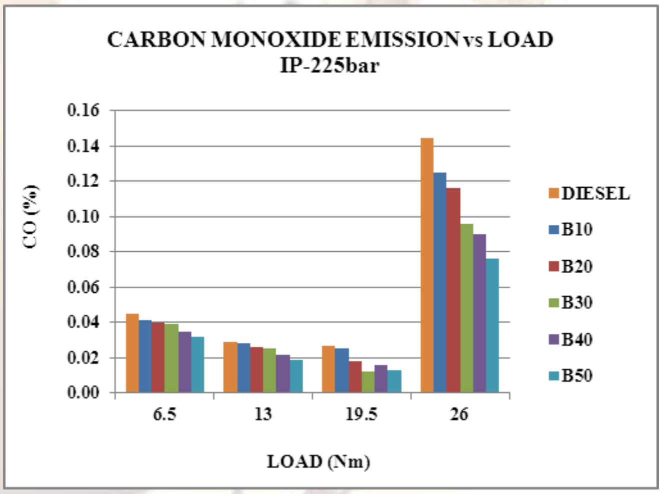

Figure 11: CO emission vs. Load for IP of 225bar

3.2.2. Hydrocarbon Emission (HC)

Hydrocarbons are measured by an exhaust analyzer in parts per million (ppm). As we know, HC is unburned fuel that remains as a result of a misfire. When combustion doesn't take place or when only part of the air/fuel charge burns, hydrocarbon levels goes up.

Fig 12 & Fig 13 shows the variation of HC emission with load for different fuels. It is observed that HC emission of the various blends was lower at partial load, but increased at higher engine load. This is due to the availability of less oxygen for the reaction when more fuel is injected into the engine cylinder at higher engine load. It is also observed from the graphs that biodiesel blends give relatively lower HC as compared to the diesel. This is because of better combustion of the biodiesel inside the combustion chamber due to the availability of excess content of oxygen in the biodiesel blends as compared to clean diesel. The HC emissions are almost same for all blends & neat diesel at both injection pressures.

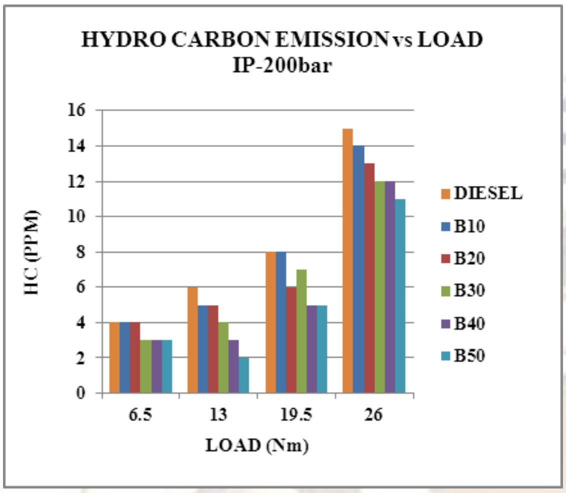

Figure 12: HC emission vs. Load for IP of 200bar

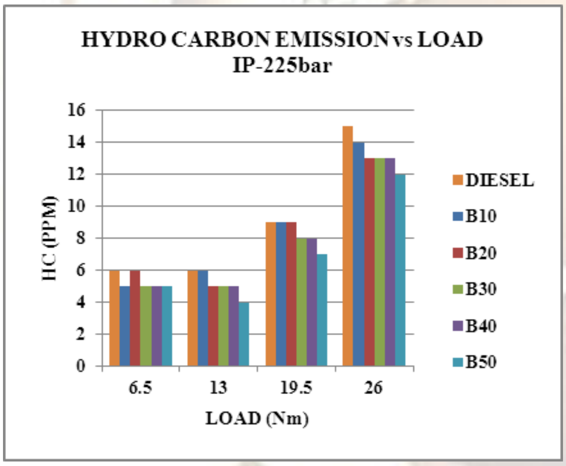

Figure 13: HC emission vs. Load for IP of 225bar

3.2.3. Nitrous Oxides Emission (NO_X)

Nitrogen Oxides are measured by an exhaust analyzer in parts per million (ppm). Nitrogen oxides are by-products of combustion. Anything which causes combustion temperatures to rise will also cause NOx emissions to rise. Misfire can also cause NOx to rise because of the increase in oxygen that it causes in the catalytic converter feed gas. NOx is more likely to cause respiratory problems such as asthma, coughing, etc.

NOx emissions are extremely undesirable. Three conditions which favor NOx formation are higher combustion temperature, more oxygen content and faster reaction rate. The above conditions are attained in biodiesel combustion very rapidly as compared to neat diesel. Hence, NOx formations for biodiesel blends are always greater than neat diesel. It can be observed from Fig 14 & Fig 15 that at higher power output conditions, due to higher peak temperatures, the NOx values are likely higher for both biodiesel and clean diesel fuel.

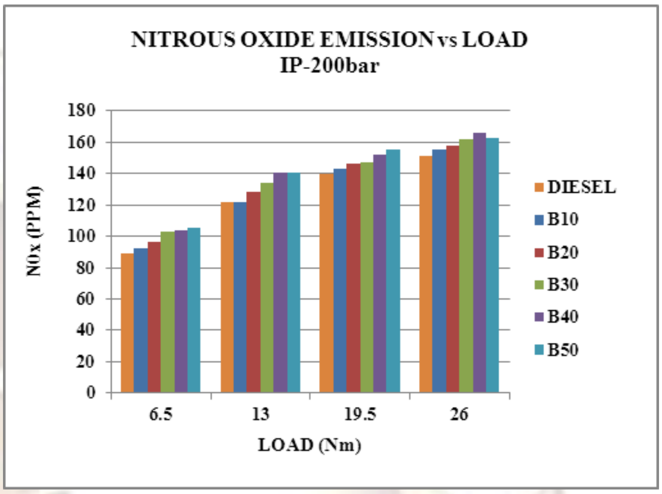

Figure 14: NO_X emission vs. Load for IP of 200bar

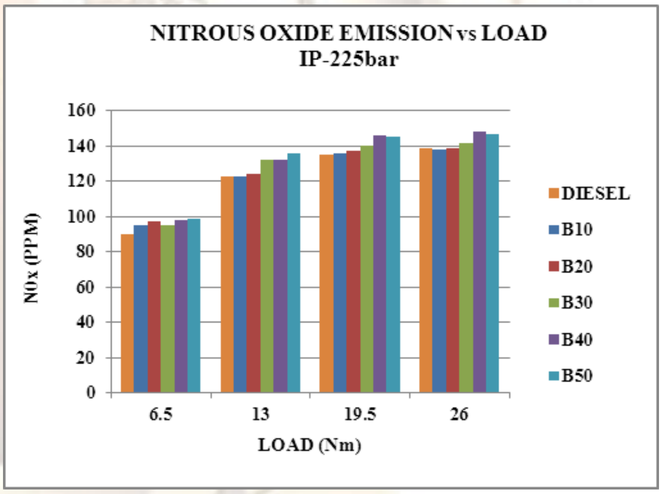

Figure 15: NO_X emission vs. Load for IP of 225bar

3.2.4. Carbon dioxide emission (CO_2)

Carbon Dioxide is measured by an exhaust analyzer in percent (%) or parts per hundred. Carbon dioxide is a by-product of efficient and complete combustion. Near perfect combustion will result in carbon dioxide levels which approach the theoretical maximum of 15.5%. Carbon dioxide levels are affected by air/fuel ratio, spark timing, and any other factors which effect combustion efficiency.

Fig 16 & Fig 17 shows the emission levels of CO_2 for various blends and diesel. Test measurements reveals that the CO_2 emission for all blends were less as compared to diesel at all loads. The rising trend of CO_2 emission with load is due to the higher fuel entry as the load increases. Biofuels contain lower carbon content as compared to diesel and hence the CO_2 emission is comparatively lower.

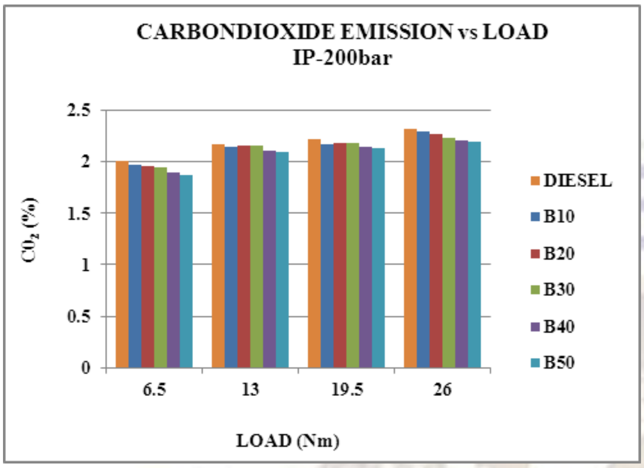

Figure 16: CO_2 emission vs. Load for IP of 200bar

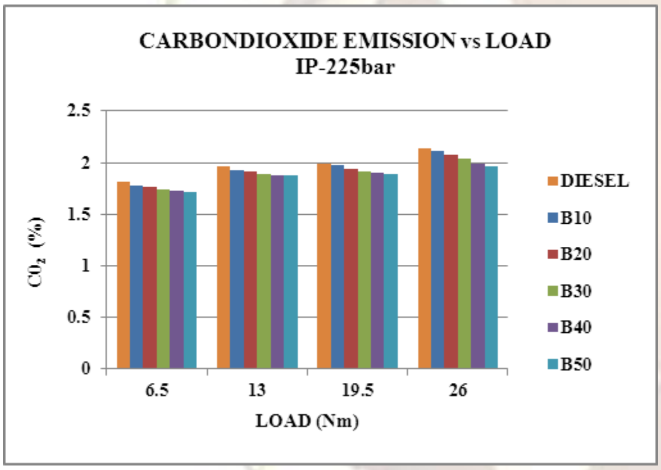

Figure 17: CO_2 emission vs. Load for IP of 225bar

4. CONCLUSION

The present investigation evaluates production of Karanja methyl ester from calcinated calcium oxide catalyst (CaO) and performance of Karanja methyl ester blends with diesel are compared with diesel in a single cylinder, 4-stroke water cooled diesel engine under varying load conditions of engine operations. The following conclusions are drawn from this investigation.

- Results obtained through the actual study suggest that calcium oxide being treated with ammonium carbonate solution and calcinated at high temperature becomes a solid super base, which shows high catalytic activity in transesterification. CaO will probably brought about as the good productivity as homogeneous catalyst (NaOH or KOH) and by taking advantage of the easy product recovery i.e. while clear phase of glycerin is easily separated and in a pure form. Under optimum conditions, the conversion of Karanja oil reached over 88 to 90%.

- KOME satisfies the important fuel properties as per ASTM specification of Biodiesel.

- The existing diesel engine performs satisfactorily on biodiesel fuel without any significant engine modifications.

- Engine performance with biodiesel does not differ greatly from that of diesel fuel. The B20 shows good brake thermal efficiency in comparison with diesel. A little increase in fuel consumption is often encountered due to the lower calorific value of the biodiesel.

- Most of the major exhaust pollutants such as CO, CO_2 and HC are reduced with the use of neat biodiesel and the blend as compared to neat diesel. But NO_X emissions increase when fuelled with diesel– biodiesel fuel blends as compared to conventional diesel fuel. This is one of the major drawbacks of biodiesel.

- Among the blends, B20 shows the better performance and emission characteristics.

- In view of the petroleum fuel shortage, biodiesel can certainly be considered as a potential alternative fuel.

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